Dr. A. Horvath
Peking Union Medical College

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CHARLES V. PIPER, Consulting Editor

THE SOYBEAN

A. Horvat

THE SOYBEAN

BY

CHARLES V. PIPER, M. S., D. S.

AGROSTOLOGIST, UNITED STATES DEPARTMENT OF AGRICULTURE

AND

WILLIAM J. MORSE, B. S. A.

AGRONOMIST, UNITED STATES DEPARTMENT OF AGRICULTURE

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PREFACE

The soybean, also known as soya or soja bean, has assumed great importance in recent years and offers far-reaching possibilities to the agriculture of the future, particularly in the United States. It is, therefore, desirable to bring together in a single volume the accumulated information concerning this crop. A complete bibliography of the soybean makes up a list of more than 1200 titles—the articles appearing in widely scattered publications. The most important are listed in an appendix to this book.

The aim has been to present the information so as to make it useful from both agricultural and commercial standpoints, not omitting, however, much that is mainly of historical or botanical interest.

The importance of the soybean lies largely in the fact that the seeds can be produced more cheaply than those of any other leguminous crop. This is due both to its high yielding capacity and to the ease of harvesting. These facts alone insure the increasing importance of the crop in the future when the land shall be called upon to yield its maximum crop of food. There can be little doubt that the soybean is destined to become one of the major American crops.

Unlike most other legumes, the soybean seed is rich in oil, which makes it one of the most important sources of vegetable oil. For the immediate future, it is likely that increased culture of the crop in the United States will be largely for oil and cake, although its use as forage will doubtless continue to increase.

Prejudice and custom are among the factors which prevent people from adopting new foods quickly. Under the stress of high prices due to war conditions, however, these factors are to some extent overcome. Already many public agencies have issued pamphlets setting forth the many ways in which soybeans and soybean meal can be used in the preparation of palatable dishes. Some of the elaborate soybean products of the Chinese and Japanese are likely to meet with increasing favor in America and Europe. Their preparation is, therefore, described in detail.

CHARLES V. PIPER.
WILLIAM J MORSE.

WASHINGTON, D. C.,
November, 1922.

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CHAPTER I

INTRODUCTION

There is a wide and growing belief that the soybean[1] (Fig. 1) is destined to become one of the leading farm crops of the United States. It is therefore desirable to bring together in a single volume the present knowledge of the crop, for the use of students, farmers and manufacturers. The aim of the book is to present especially the knowledge useful from agricultural and commercial viewpoints, not omitting however much that is mainly of historical or botanical interest.

FIG. 1.—Typical soybean plant.

Name of the Plant.—The soybean rarely called soy pea is also known as soja bean or soya bean, different variations of the same word. Botanically it has been referred to in literature usually as *Glycine hispida*. Recently the botanical history of the plant has been clarified, with the result that the botanical name of the of plant became *Glycine max* under the International Rule of botanical nomenclature or *Soja max* under the American rules.

Origin.—The soybean is native to Eastern Asia, the wild form of the plant formerly called *Glycine ussuriensis* being known to occur in China, Manchuria and Korea. The wild plant is a

[1] "In view of the tendency of writers both in experiment station literature and in the agricultural press to use *soybean* as a single word, the authors have adopted this form throughout. Unquestionably this is the form to which the term is tending in the evolution of language. Indeed, the use of *soybean* as a single word has been adopted by the experiment stations of Illinois, Indiana, Mississippi, Missouri, New Jersey, North Carolina, Ohio, South Dakota, and Wisconsin.

slender twining vine (Fig. 2) but a complete series of forms connect it with the typical upright cultivated varieties. There is thus scarcely room to doubt the origin of the cultivated plant as there is no other wild plant that can possibly be its ancestor.

The culture of the soybean is recorded in ancient Chinese literature and undoubtedly dates from a period long before the time of written documents.

Fig. 2.—Plant of wild soybean.

Literature.—A complete list of the published contributions to the knowledge of the soybean numbers about 1,200 titles, printed in many languages and in numerous journals. Only the more important are cited in this book.

Use by the Chinese and Japanese.—Among the Chinese and Japanese the soybean has been a crop of prime importance since ancient times. To a great extent it helps supply the population with the nitrogenous food needed in the diet. Besides it is one of the few plant seeds that contains both of the vitamines necessary to life in higher animals including man. To a large extent the soybean is eaten by Oriental peoples in the form of fermented products, and only to a limited degree or in certain localities in the way that Occidental people consume beans. This custom has led to the idea that the soybean was not very suitable for human food when prepared in the manner of ordinary beans. The fact was overlooked that the Mongolian peoples prepare all kinds of beans intended for food by elaborate methods practically unknown to western peoples. Such complex products of the soybean did not justify the conclusion that the bean was not a good food when prepared in simple ways. The recent large use of the soybean for human food in both Europe and the United States has dispelled to a great degree the erroneous ideas formerly held concerning its desirability for human consumption.

Present Importance.—At the present time the soybean is a crop of large importance in Japan, Manchuria, Mongolia and Korea; of increasing importance in the United States and a few areas in Europe; of promising value in South Africa, Argentina, Australia and Northern India. The actual extent of its present commercial value is discussed later in detail.

The total area of soybeans for seed production in the United States in 1920 according to acreage estimates of the United States Department of Agriculture was 190,000 acres. It is estimated that not more than 20 per cent. of the soybeans are harvested for seed, the greater per cent. of the acreage being utilized for forage, pasture and ensilage. On this basis, the total acreage of soybeans grown in 1920 would be 950,000 acres.

The different states in order of their soybean acreage for seed production for 1920 are as follows:

TABLE I.—ACREAGE, PRODUCTION AND YIELD TO THE ACRE OF SOYBEAN SEED IN THE UNITED STATES[1]

State	Acreage			Production			Yield to Acre		
	1920, acres	1919, acres	1918, acres	1920, bu.	1919, bu.	1918, bu.	1920, bu.	1919, bu.	1918, bu.
N. Carolina.....	91,000	96,000	85,000	1,638,000	1,373,000	1,700,000	18.0	14.3	20.0
Virginia........	30,000	30,000	28,000	570,000	555,000	630,000	19.0	18.5	22.5
Alabama.......	23,000	7,000	11,000	228,000	59.000	110,000	9.9	9.4	10.0
Illinois.........	8,000	6,000	5,000	92,000	60,000	65,000	11.5	10.0	13.0
Ohio...........	8,000	6,000	2,000	64,000	42,000	14,000	8.0	7.0	7.0
Kentucky.....	8,000	7,000	7,000	120,000	105,000	84,000	15.0	15.0	12.0
Missouri........	7,000	7,000	5,000	133,000	98,000	40,000	19.0	14.0	8.0
Tennessee......	5,000	5,000	2,000	50,000	40,000	10,000	10.0	8.0	5.0
Wisconsin......	4,000	2,000	1,000	28,000	15,000	8,000	7.0	7.5	8.0
Indiana........	3,000	3,000	1,000	42,000	36,000	15,000	14.0	12.0	15.0
Georgia........	2,000	2,000	1,000	22,000	20,000	11,000	11.0	10.0	11.0
Pennsylvania...	....	2,000	2,000	....	36,000	34,000	....	18.0	17.0
S. Carolina.....	....	1,000	1,000	....	6,000	6,000	....	6.0	6.0
Mississippi......	1,000	1,000	8,000	15,000	15,000	120,000	15.0	15.0	15.0
Other..........	....	....	10,000	....	177,000	....	....	17.7	
United States...	190,000	175,000	169,000	3,002,000	2,460,000	3,024,000	15.8	14.1	17.9

Future Prospects in the United States.—The soybean has been a farm crop in the United States of some importance since about 1880, and used mainly as a forage crop. Even for this purpose it has increased steadily in favor as revealed by the increasing acreage from year to year. As a forage crop alone it is not likely

[1] Monthly Crop Reporter, v. 6, no. 12, Dec., 1920: 144.

that the soybean would become one of the major field crops in the United States. The reasons for this are two fold.

First.—The high yielding capacity of the soybean and the cheapness of harvesting the seed, in both which respects soybeans excel other legumes. The seeds and the numerous manufactured products thereof furnish very valuable human foods, which is certain to be used extensively if for no other reason than their cheapness. Of more immediate importance are soybean oil and soybean cake. Extensive data show that the United States can successfully compete with the Orient in raising soybeans because the use of machinery counterbalances the cheaper Oriental labor. The market demands for vegetable oils and oil meals are far greater than the supply and there is no reason to expect that the supply will exceed the demand.

Second.—In general the soybean proves to be a more profitable crop than oats, the crop which it will mainly replace in Corn Belt rotations. This in itself would seem to assure a very large and rapid increase in soybean acreage. Incidentally the fact of the soybean being a legume will probably make its effect on the succeeding crop more favorable than is the case with oats.

Recognition of the Possibilities.—The large recent increase in acreage of the soybean especially in the Corn Belt has already stimulated manufacturers to take advantage of the industrial uses of the crop. American factories are now producing from the soybean, oil, meal, flour, biscuits, milk powder, chocolate, soy sauce, and special foods for infants and invalids. The oil mills in the Corn Belt are prepared to crush in 1922 great quantities of soybeans. One of them figures at a minimum of 150,000 tons; another 125,000 tons. North Carolina mills will also crush soybeans in 1922. The prospects are however that the 1923 acreage planted to soybeans will be very greatly increased, which in itself will require that a larger amount of seed be held over for planting.

CHAPTER II

THE COMMERCIAL STATUS OF THE SOYBEAN

The trade in soybeans prior to 1908 was largely confined to Oriental countries, particularly China, Manchuria, and Japan. Since that time there has been a rapidly increasing importance of the seed and the commercial products thereof in the world's trade. The European War, 1914–1918, interfered greatly in the normal evolution and development of this trade, but there can be no doubt that under peace conditions it will continue to grow in importance. The statistics of production and commerce are somewhat fragmentary but nevertheless illuminating.

Manchuria and China.—Manchuria produces at the present time (1921) larger quantities of soybeans that all other countries combined. The bean trade was an ancient and flourishing institution when the ports of China were first opened to the commerce of the western world. In 1835 Newchwang (Fig. 3) was an important port of shipment for the great coastal trade in beans, bean cake and oil with the ports of the southern provinces, Java and other tropical regions. For a few years after the opening of the customs at Chinese ports in 1865, the trade in beans and bean products developed rapidly but until 1891 its progress was more or less erratic, due to combinations of disturbing factors in Chinese commercial history.

After the China-Japan war in 1894, the bean trade developed rapidly, and in 1900 was firmly established. Prior to the Russo-Japanese war in 1904, soybeans and their products were exported almost entirely to Asiatic countries, Japan being the principal consumer. During this war, the local demand greatly increased the production of the crop throughout Manchuria. After the withdrawal of the troops, however, it became necessary to find new markets for the surplus beans. Trial shipments were made in about 1908 by Japanese firms to several English oil mills. The suitability of the seed for oil and oil cake was quickly recognized, and orders for large consignments were made. The bean trade grew rapidly, extending to other European countries and to America.

That the development of the bean trade will continue to expand seems highly probable. The agricultural population of Manchuria is rapidly increasing under Government encouragement. New railways are being built, opening the way to the promotion of the older regions to the fullest capacity and besides developing other regions. Moreover, the soybean in Manchuria is raised under ideal climatic conditions and by very cheap labor. The

FIG. 3.—A fleet of junks engaged in carrying soybeans to Newchwang, Manchuria, from different points in the interior, taking away bean oil and bean cake to other places. (*Photographed by F. N. Meyer.*)

competition to secure the bean and its products in Europe and America indicates that the trade is upon a firmly established basis.

Acreage and Production.—From available statistics it is shown that in 1914, northern Manchuria had under cultivation of beans, 2,248,561 acres and southern Manchuria, 1,082,496 acres, making a total of 3,331,057 acres for Manchuria. According to a report of the American consul at Mukden, the 1921 crop of soybeans in Manchuria was 4,520,000 tons, and in inner Mongolia 431,000 tons. No statistics are available for showing the acreage devoted

to the culture of soybeans in China. The first careful estimate of production of soybeans in Manchuria was made in 1900 by Sir A. Hosie (1904) who calculated the amount at 600,000 tons. Other than this estimate and the later estimates from the reports of the British and American Consuls and the South Manchurian Railway, scarcely any data are available on the production of beans in Manchuria. The following table shows the estimates of the bean production for various years obtained from American and British Consular reports.

TABLE II.—ESTIMATES OF SOYBEAN PRODUCTION OF MANCHURIA FOR VARIOUS YEARS

1906, tons	1907, tons	1908, tons	1909, tons	1910, tons	1913, tons	1914, tons	1921, tons
600,000	600,000 to 900,000	1,150,000	1,150,000	1,400,000	1,200,000	1,150,000	4,520,000

Cost of Production.—Reliable statistics as to cost of production and yield of beans per acre in Manchuria are not available. According to data secured from bean growers in the vicinity of Mukden by the American Consul in 1910, the approximate cost per acre is placed at $4.42, as shown in the following table:

TABLE III.—COST OF PRODUCTION OF SOYBEANS PER ACRE IN MANCHURIA, 1910

	U. S. GOLD
Seed	$0.48
Labor	1.44
Land rent	1.68
Land tax	0.05
School and police tax	0.29
Cartage and horse feed	0.48
Total	$4.42

With an average yield of 22 bu. to the acre around Mukden, the average cost per bushel would be 20 cents, U. S. Gold, or $6.68 per ton, which was reported to represent the total cost laid down at market at that time.

Methods of Marketing.—About 80 per cent. of the bean dealers in Manchuria purchase the beans in the growing districts, the remaining 20 per cent. buying in the various markets. In recent years there has been a growing tendency to establish

collecting centers for accumulating the beans. At Mukden the beans are mostly brought in by the growers themselves (Fig. 4)

Fig. 4.—Soybeans brought to bean center in winter in Manchuria.

Fig. 5.—Chinese bean cart loaded with beans in Manchuria.

and are sold to the highest bidders, provided the beans have not been contracted for before the harvest. In most of the grow-

ing districts, certain places are recognized as collecting centers to which the bean growers bring their products by cart (Fig. 5) and sell them to the collectors who are sometimes local traders and sometimes agents of large dealers. The collectors transport the beans by rail to the large dealers in the cities. No grading of beans is attempted by the small collectors, the stored beans being of all varieties and mixed more or less with sand and trash. The exporters buy the beans simply by weight, but before shipment the beans are sorted.

In south Manchuria the beans generally pass through only a few hands from the growers to the collectors located in the producing districts; and from them to the large handlers who may sell them to the bean mills or to exporters. However, beans from distant districts or north Manchuria may pass through many hands.

In some instances, money is advanced by the buyers on growing crops. In most cases such advances are made to the farmers who cultivate rented lands and are, therefore, not well off financially. In return for advances, the farmer contracts to sell his beans at from 10 to 20 cents less than the normal value on each 40 lb. The bean growers who farm their own land, are as a rule richer and do not require any financial advances.

In the larger bean markets of Manchuria, such as Mukden, Newchwang and Changchun, the native dealers speculate more or less in beans. In some cases the buyers collect large quantities and hold them for higher prices; in other cases they speculate on growing crops by selling on a forward or future contract in which they will often agree to sell beans for future delivery at a price cheaper than the market price prevailing at the time the contract is made. In future contract deals, the buyer is generally required to pay 8 per cent. on the full contract price for the beans, the seller in return furnishing the buyer with an adequate guarantee for delivery These methods of buying and selling beans are confined to large dealers and do not as a rule directly affect the grower.

The sale of beans in the interior of Manchuria is generally conducted on a strictly cash basis. However, in such places where the agents of the larger bean firms sell foreign and Chinese goods, these goods are often sold on credit against the growing bean crops, in which case the prices of the goods thus furnished are somewhat higher than the ruling market quotations, as the buyers

wish to obtain sufficient profit to cover the interest on the money invested in the goods.

The facilities for transporting beans from the grower to the market are very poor and no important changes have yet been

FIG. 6.—Type of cart and method of hauling soybeans in Manchuria.

made in the routes over which beans are brought. The beans are not moved by the grower until the roads are frozen or snow has fallen, leaving the farmers to bring them across country

FIG. 7.—In winter the Manchurian farmers haul the bean crop to market on sleds.

by cart (Fig. 6) or on sleds (Fig. 7). Very often the movement of beans is delayed on account of the lateness of freezing or of sufficient snow, thus causing considerable fluctuation of prices in the bean market.

Oil and Cake Industry.—In Manchuria the manufacture of oil and oil cake is not confined wholly to large cities, as every small center of bean production has its native mill in which the method of extracting the oil is decidedly primitive. The mills now in operation in the large centers of production include Chinese steam mills, Japanese hydraulic mills, small oil motor mills, solvent extraction mills, and crush-stone mills worked by animals. At Newchwang, 22 mills produced in oil for the years 1907, 1908 and 1909, 18,662, 21,328 and 23,994 tons respectively; in cake, 193,018, 220,745 and 248,333 tons respectively. At Dairen, 40 native mills turned out 5,000 oil cakes daily, while two large modern hydraulic mills produced 4,000 oil cakes daily.

The following table gives the monthly production of 11 oil mills situated at Newchwang.

Table IV.—Monthly Capacity of Steam Oil Mills at Newchwang, Manchuria,[1] 1917

Name of oil mill	No. of presses	Oil, (pounds)	Cake, (pounds)
Jih Hsin Chang	150	719,820	17,995,500
Yung Tung Ching	60	279,930	5,998,500
Tung Shun Yung	40	191,952	4,798,800
Tung Yung Mao	100	479,880	11,997,000
Hsi I Shun	60	279,930	7,198,200
Hsing Shun Knei	60	279,930	7,198,200
Yü Fa Hsiang	50	239,940	5,998,500
Hou Fa Ho	40	191,952	4,798,800
Ying Fa Ho	40	191,952	4,798,800
Hsing Mao Tung	30	143,964	3,599,100
Kodera Yoko	20	479,880	11,997,000

The oil and cake industry has gradually increased throughout Manchuria, this being due largely to the exportations to Europe and America. The bean oil industry has developed very rapidly and in view of the increasing demands for vegetable oils no doubt will become much greater.

The methods of conveying oil from Manchurian ports to foreign countries are for the most part at present not satisfactory. The

[1] Report by the Consul General on Bean Production in the Mukden Consular District.

bean oil is now carried in old kerosene oil tins, in drums or in casks. Much complaint is made of loss by leakage with the drums, while the casks are not so suitable for storing as tins in cases. The solution of the problem of carrying oil apparently is the tank steamer, which would carry the bean oil as a return cargo.

Exports.—Statistics on exports from Newchwang show that in 1864, 54,386 tons of beans, 56,119 tons of cake and 488 tons of oil were exported in that year. In 1867, these figures had risen to over 66,500 tons of beans, 77,514 tons of bean cake, and 1,533 tons of oil.

The ports of Antung, Dairen and Newchwang are the principal centers of export from southern Manchuria. The exports of beans, bean cake and bean oil passing through these ports for the years 1909 to 1913 inclusive, are shown in the following table:

Table V.—Exports of Soybeans, Bean Cake, and Bean Oil from the Principal Ports of South Manchuria, 1909 to 1913, Inclusive[1]

Exports and Ports	1909, tons	1910, tons	1911, tons	1912, tons	1913, tons
Soybeans:					
Antung	1,643.4	136.1	4,591.5	3,639.8	5,225.6
Dairen	512,469.0	359,665.3	268,732.4	182,628.6	169,300.8
Newchwang	237,020.6	174,562.7	154,187.3	129,985.1	105,341.8
Total	751,133.0	534,364.1	427,511.2	316,253.5	279,868.2
Bean cake:					
Antung	16,349.6	12,054.0	33,166.5	40,111.1	42,322.2
Dairen	318,825.5	277,423.7	463,546.2	378,722.7	566,135.7
Newchwang	356,499.4	327,098.5	386,599.1	282,877.9	298,364.0
Total	691,674.5	616,576.2	883,311.8	701,711.7	906,821.9
Bean oil:					
Antung	92.7	149.6	365.7	558.4	192.1
Dairen	10,850.3	18,753.2	33,729.7	37,466.7	43,392.3
Newchwang	37,875.2	21,356.2	28,039.1	21,826.2	20,752.9
Total	48,818.2	40,259.0	62,134.5	59,851.3	64,337.3

[1] Compiled from U. S. Dept. Com., Daily Cons. and Trade Rpts., No. 115, p. 922, May 16, 1914. (Hanson, G. C. Manchuria's soybean trade.)

Beans from north Manchuria are exported chiefly through Vladivostok. The export figures for the years 1912 and 1913 amount to 338,451 tons and 391,410 tons respectively. Adding these quantities to the exports of south Manchuria, gives 654,705 tons for 1912 and 599,278 tons for 1913, which may be taken as representing the total exports of beans from Manchuria for these two years.

Japan.—In production and utilization, the soybean occupies a most important position among the various legumes grown for seed in Japan. It is extensively cultivated from Hokkaido province in the north, to Formosa in the south. The data relative to the production and commerce of the soybean and soybean products in Japan are more extensive than for China and Manchuria, and furnish rather valuable information concerning the importance of this crop.

Acreage and Production.—The soybean is grown by the Japanese farmers mainly for grain and not to any considerable extent as a green manure crop. The average annual production of seed is about 18,000,000 bu. The following table shows the acreage and production in Japan during the decade 1897 to 1919. The principal bean-producing provinces are Hokkaido, Ibaraki, Saitama, Iwate, Niigata, Nagasaki and Kumamoto, but there is no province where the annual production does not exceed 50,000 bu. The province of Hokkaido has the largest acreage and produces the highest quantity and best quality of beans.

Table VI.—Five-year Averages of Acreage, Production and Yield per Acre of Soybeans in Japan[1]

Five-year periods	Acreage, acres	Production, bu.	Yield per acre, bu.
1897–1901	1,129,000	17,112,000	15.16
1902–1906	1,124,000	17,137,000	15.26
1907–1911	1,183,000	18,268,000	15.42
1912–1916	1,153,000	17,584,000	15.25
1917–1919	1,072,000	18,163,000	16.46

Utilization.—The soybean forms one of the most important

[1] Twentieth Financial and Economic Annual of Japan, 1920.

articles of food in Japan. It is one of the principal ingredients of soy sauce, miso, tofu and natto. The beans are eaten boiled or baked or in powder form for soups. Sometimes they are picked green, boiled and served cold with soy sauce, and sometimes as a salad. A vegetable milk is also produced from the bean forming the basis for the manufacture of vegetable cheese. The milk is not only used in the fresh state, but a form of condensed milk is also manufactured from it. All these foodstuffs are used daily in the Japanese homes. For the poorer classes they are the principal source of protein and considered indispensable as articles of food in the diet. Owing to their large utilization as human food, the domestic soybeans are used only to a limited extent in the feeding of live stock. To supply the protein ration for animals deficient in that nutrient, the beans are sometimes boiled and fed mixed with straw, barley and bran. The beans, especially those imported from China and Manchuria, are used extensively in the production of oil and cake. The oil is used as an article of diet and for various technical uses, while the residue or bean cake is used extensively as a fertilizer and as a cattle feed.

Cost of Production and Market Prices.—Accurate data as to cost of production are not available, but estimates made by Japanese agricultural experts, place it about $10.00 per acre, exclusive of taxes, or about 65 cents per bushel.

The beans produced in Japan are considered to be superior in quality to those of Manchuria and Chosen (Korea) and are used exclusively in the manufacture of food products. Prior to 1914 the prevailing wholesale price of domestic beans in Japan was about $1.00 per bushel while for imported beans it was about 70 cents per bushel.

Imports.—Japan has always been a large consumer of soybeans from China and Manchuria, the greater part of the beans being used in the manufacture of oil and bean cake. In amount and value the importation of soybeans is second only to rice. The amounts and values of soybeans imported are shown in table VII for the years 1903 to 1907 inclusive, and 1911 to 1914 inclusive.

Table VII.—Amount and Value of Soybeans Imported by Japan

Year	Quantity, tons	Value
1903[1]	146,971	$3,184,540
1904[1]	144,231	3,558,133
1905[1]	193,479	4,915,128
1906[1]	176,040	4,504,086
1907[1]	177,365	4,792,161
1911[2]	162,703	
1912[2]	103,416	
1913[2]	90,651	
1914[2]	139,222	

The bean cake manufactured in Japan forms only a small proportion of the total used by Japanese farmers. Large amounts of bean cake are annually imported as shown in the following table. Previous to 1903, bean cake was the largest in amount among imported fertilizers.

Table VIII.—Importations of Soybean Cake and Bean Oil into Japan

Year	Soybean cake			Soybean oil
	Quantity, tons	Value	Percentage of import of bean cake against the total import of other fertilizers	Quantity, tons
1903[3]	216,198	$3,807,685	57.8	
1904[3]	70,595	1,629,100	32.3	
1905[3]	225,180	4,525,043	40.5	
1906[3]	289,459	6,458,330		
1907[3]	367,210	8,715,489	44.8	
1911[4]	357,362	....	....	9,340
1912[4]	357,752	....	....	10,889
1913[4]	492,985	....	....	3,964
1914[4]	447,080	....	....	4,107

Exports.—In addition to supplying domestic demands, Japan has exported beans, bean oil, miso (bean cheese) and soy sauce

[1] Agriculture in Japan, Department of Agriculture and Commerce, Agricultural Bureau, 1908, p. 227.

[2] Compiled from Dairen Wharf Office Returns, 1911–1914.

[3] Agriculture in Japan, Department of Agriculture and Commerce, Agricultural Bureau, 1908, p. 228.

[4] Compiled from Dairen Wharf Office Returns, 1911–1914.

in large quantities to American and European countries as shown in the following tables. The exports of beans and bean oil have only become of importance since the development of the American and European trade. Prior to 1914, soybeans were not listed separately.

TABLE IX.—QUANTITY AND VALUE OF EXPORTS OF SOYBEANS AND SOYBEAN OIL FROM JAPAN TO FOREIGN COUNTRIES, 1913 AND 1914[1]

Country of destination	Soybeans		Soybean oil			
	1914		1913		1914	
	Quantity, lb.	Value	Quantity, lb.	Value	Quantity, lb.	Value
China	62,820	$ 1,372	220,155	$11,328	184,104	$ 10,198
United Kingdom	589	21	214,491	11,570	1,019,854	48,687
France	....	....	73,890	3,907		
Germany	....	....	66	2	10,979	588
Belgium	....	....	69,057	3,405	333,735	16,573
United States	421,011	10,125	658,393	34,386	365,478	19,393
Hawaii	203,560	5,296				
British America	246,175	4,540	56,218	3,234	69,652	3,196
Australia	18,070	475	587,413	30,101	120,240	748
Other countries	20,967	504	....	....	274,080	18,542
Total	973,192	22,333	1,879,683	97,933	2,378,122	117,925

TABLE X.—QUANTITY AND VALUE OF EXPORTS OF MISO (BEAN CHEESE) AND SHOYU SAUCE, 1903 TO 1907 INCLUSIVE[2]

Year	Miso (bean cheese)		Shoyu sauce	
	Quantity, lb.	Value,	Quantity, lb.	Value
1903	2,204,521.00	$ 34,647	5,922,357	$204,959
1904	4,884,691.68	88,880	7,892,802	276,837
1905	7,503,650.00	132,652	12,506,892	440,076
1906	5,923,855.00	111,020	12,425,367	476,176
1907	6,863,953.00	135,833	13,210,743	541,425

Europe.—While many earlier attempts had been made to introduce the soybean and its products into European countries,

[1] Compiled from Annual Return of the Foreign Trade of the Empire of Japan, 1914.

[2] Agriculture in Japan, Department of Agriculture and Commerce, Agricultural Bureau, 1908, p. 227.

it was not until about 1908 that the bean received serious consideration as a product of economic importance. About 1900, however, soybeans were imported by an English firm as, on account of their being practically free from starch, it was thought they would make an excellent food for patients suffering with diabetes. Germany and Holland also imported small amounts of soybeans for the same purpose and many special food products were manufactured by firms in these countries.

Growth of the Trade.—Owing to the inferior quality of the product received, due principally to the poor shipping conditions, the first attempts to introduce the soybean as an oil seed were generally unsuccessful. The first large importation of beans, 400 to 500 tons, was made in 1907 by a crusher at Liverpool, the beans being shipped from Hankow and delivered at Liverpool at a cost of $50.00 per ton. It was found that an oil valuable to soap manufacturers could be produced and that the by-products, cake and meal, both high in protein, could be utilized by manufacturers of mixed feeds.

After 1907 importations gradually increased and the beans were received in much better condition than those of the first trial shipment. At this time also, impetus was given to the manufacture of soybean products by a shortage of cottonseed and linseed. In February 1908, a cargo of 9,000 tons of beans was received at Hull, the selling price of the beans being $32.00 per ton, C.I.F. It was found by importing in cargo lots, the price was lowered $4.40 per ton. In June 1909 beans sold for $28.75 per ton but by January 1910 had risen to $41.00 per ton.

At first England enjoyed the monopoly of trade in soybeans. Nearly all of the first large importations of beans were taken by England where many of the large oil mills devoted their plants entirely to the crushing of soybeans. Several of these mills conducted series of tests, demonstrating the value of the cake, meal and oil.

Utilization of the soybean as an oil seed extended rapidly to other European countries. The fact that they were called beans, prevented them from having a wider market at the beginning of the large importations, since in Germany, France and Austria, oil seeds were on the free list, but beans were subject to a tax. These countries realizing the importance of the bean, soon placed it on the free list and the monopoly in the trade of soybean products was taken from England.

2

Extent of the Trade.—The importations of beans from Manchuria and Japan soon reached enormous proportions. In 1909, 412,757 tons; in 1910, 442,669 tons; and in 1911, 321,940 tons of beans were imported by European countries. That the soybean and its products became important competitors of other oil seeds and their products is shown in the following table:

TABLE XI.—QUANTITY AND VALUE OF IMPORTS OF SOYBEANS, BEAN CAKE, AND BEAN OIL BY EUROPEAN COUNTRIES, 1912 TO 1914, INCLUSIVE[1]

Product and country	1912		1913		1914	
	Quantity, tons	Value	Quantity, tons	Value	Quantity, tons	Value
Soybeans:						
United Kingdom....	188,760	$7,630,477	76,452	$3,093,863	71,161	$2,886,759
Germany...........	96,068	3,974,837	107,504	3,974,838	12,843	480,401
Netherlands........	42,373	1,592,690	27,119	1,019,317	19,308	725,721
Russia.............	695	30,250	267,036	6,461,739		
Belgium............	1,625	61,095	6,438	199,684	1,002	37,564
Denmark...........	412	14,035	4,425	115,975	8,187	357,434
France.............	....	....	34,318	918,008		
Total............	329,933	$13,303.384	523,293	$15,783,424	112,501	$4,487,879
Soybean cake:						
Netherlands........	23,852	836,269	7,230	250,459	1,235	43,964
Germany...........	7,080	252,912	3,260	111,015	1,201	41,258
Russia.............	2,059	72,136	21,969	396,944	195	6,507
Denmark...........	7,620	252,834	15,490	520,857	4,964	164,332
Total............	46,611	1,414,151	47,949	1,279,275	7,595	256,061
Soybean oil:						
Netherlands........	4,558	250,422	2,828	154,691	10,015	547,820
Belgium............	2,082	278,569	363	45,389	137	16,957
Italy..............	2,252	356,006	4,642	735,490	5,830	953,403
Sweden............	1,116	154,434	578	78,491	313	41,867
Austria............	617	99,797	1,314	206,078	1,395	224,565
Germany...........	10,902	1,450,134	3,090	396,032	2,459	296,966
France.............	1,693	249,486	83	11,397	208	26,917
Russia.............	....	....	5,150	508,076		
United Kingdom....	....	....	95	11,570	455	48,687
Total............	23,220	2,838,848	18,143	2,147,214	20,812	2,157,182

Utilization.—The principal use of soybean oil at first was in the manufacture of soft soaps, as it was found that the oil did not chill easily and was difficult to handle in making hard soap.

[1] Complied from Koninkryk der Nederlanden, Statistiek van den in-, uit- en doorvoer; Annual Statement of the Trade of the United Kingdom with Foreign Countries and British Possessions; Statistik des Deutschen Reichs, Auswartiger Handel.

However, some European soap manufacturers soon claimed to have found a secret process by means of which they could utilize the oil in the manufacture of the best grades of hard soap. Other uses were found for the oil and it entered largely into the manufacture of butter and lard substitutes and edible oil.

Soybean cake or meal in the beginning of the trade found its largest outlet in Denmark, about 150,000 tons having been purchased from English oil mills in 1910. The trade in the cake or meal extended rapidly to Sweden, Norway, Holland and the northern part of Germany. The United Kingdom is not a large user of the bean cake. It is however used to a considerable extent by Scotch farmers and to a small extent by Irish and English farmers. The cake manufactured into a flour, has gradually assumed an important place as a foodstuff and as such is utilized in many European countries.

United States.—The soybean was introduced into the United States as early as 1804, but it is only within recent years that it has become a crop of much importance. Until recently it has been grown primarily as a forage crop, although a constantly increasing demand for the seed has led to the development of very profitable soybean seed industries in many sections of the cotton and corn belts. The extensive area over which the soybean can be profitably grown, the large yield of seed, the ease of growing and harvesting the crop, the value of the beans for both human and animal food, and the increasing demand for vegetable oils, all tend to give this crop a high potential importance and to assure its great agricultural development in America.

Manufacture of Oil and Cake.—Following the marked success in the utilization of the soybean as an oil seed in European countries, interest in the possibilities of the oil and meal became manifest in the United States. Soap and paint manufacturers in their search for new oils, conducted extensive experiments with soybean oil which soon led to large importations of the oil from Asiatic countries and Europe. The first extensive work in the United States with the soybean as an oil seed was entered upon about 1910 by an oil mill on the Pacific Coast. The beans containing from 15 per cent. to 19 per cent. oil were imported from Manchuria and the importations, most of which are used in the manufacture of oil and cake, have gradually increased, as shown in Table XIII.

Although efforts have been made for several years to interest the cotton-oil mills of the South in the possibilities of American grown soybeans, no extensive work was entered upon until the latter part of 1915. A shortage of cottonseed in the South and a surplus of soybean seed in the seed-producing centers led to an increased interest in the soybean as a source of oil and cake. Several cotton-oil mills after preliminary tests, entered upon an extensive production of soybean oil and meal, crushing about 100,000 bu. the first season. During the seasons of 1917 and 1918, only a small quantity of domestic grown beans was crushed for oil, this being due principally to the high price of the seed which was in large demand for food and planting. Very large quantities of soybeans, however, during these seasons were imported from Manchuria and utilized by the cotton-oil mills throughout the South.

The use of soybean oil has become firmly established, the largest quantities being used by manufacturers of soap, paints, lard and butter substitutes. The cake or meal is being used extensively as a cattle feed and also as an ingredient of fertilizer, much the same as cottonseed meal When the value of the meal becomes properly appreciated for the production of beef and butter, there will be practically an unlimited demand for it as a feed In the dairy countries of Europe, oil meals form a most important part in the stock rations. Denmark feeds more than a tenth of a ton of cottonseed cake (besides other kinds of oil cake) per head of cattle per year. If the cattle in the United States were to be fed at the same rate, the total oil cake or meal of all kinds produced in this country would be insufficient to supply the demand.

Soybean oil will doubtless become a strong competitor of other vegetable oils for which the demand is constantly increasing, both in this country and in Europe.

Use as Food.—Numerous food industries have developed in recent years, in which the soybean is utilized in many ways. The canning factories in various parts of the country have packed many thousands of bushels of American grown beans as baked pork and beans. The matured beans have been placed on sale in most of the large cities as dried beans, and used in the same manner as the navy bean. Soybean flour has become established on the market, although at the present time principally as a special food. In some of the Pacific Coast states, however,

the flour has been placed quite generally on the market and can be as readily procured as corn meal, graham flour, and the like. Soy sauce is now being manufactured in a few places on a small scale. Various other food-stuffs are in course of manufacture with a view of utilizing the high nutritive value of the bean.

Prices, Competition and Imports.—It seems quite evident that the American planter can compete on European and home markets with the Manchurian market at the prices prevailing the past few years, although the cotton-oil mills estimate that the soybean under normal conditions cannot be worked profitably at a much higher price than $1.00 per bushel and then only when the price of cottonseed is dearer. Available statistics in Table XII show that the oil mills in Europe have been paying in many instances, higher prices for soybeans than for cottonseed.

TABLE XII.—COMPARATIVE PRICES PER TON OF COTTONSEED AND SOYBEANS IN EUROPEAN MARKETS, 1911 TO 1914, INCLUSIVE

Country	1911		1912		1913		1914	
	Soybeans	Cottonseed	Soybeans	Cottonseed	Soybeans	Cottonseed	Soybeans	Cottonseed
United Kingdom.....	$35.18	$35.86	$40.42	$37.07	$40.47	$36.76	$40.57	$33.63
Germany............	37.48	38.78	41.37	39.77	36.97	40.37	37.40	
Average...........	$36.33	$37.32	$40.89	$38.42	$38.72	$38.56		

Although the selling price, F.O.B. Manchuria ports ranges from $30.00 to $55.00 per ton, the transportation under normal conditions makes the price approximately $40.00 at American and European ports. If the American grower can raise the beans profitably at $1.00 per bushel of 60 lb. the higher yields of seed obtained and the planting and harvesting of the crop by machinery in the United States should enable him to compete with the Manchurian product, not only on the home market, but also on the European market.

The possibilities of developing a great manufacturing industry with American grown seed are excellent. The large annual importations of soybeans, oil and cake into the United States as shown in table XIII seem to indicate a most ready market for these products.

TABLE XIII.—QUANTITY AND VALUE OF SOYBEANS, SOYBEAN CAKE, AND SOYBEAN OIL IMPORTED INTO THE UNITED STATES, 1910 TO 1920, INCLUSIVE[1]

Year	Soybeans		Soybean cake		Soybean oil	
	Quantity, lb.	Value	Quantity, lb.	Value	Quantity, lb.	Value
1910	....	....	....	....	Not stated	$ 1,019,842
1911	....	....	2,115,422[2]	$ 59,626	41,105,920	2,555,707
1912	....	....	2,416,052[2]	64,350	28,019,560	1,576,968
1913	....	....	7,004,803	93,002	12,340,185	635,882
1914	1,929,435	$ 49,507	3,163,260	38,255	16,360,452	830,790
1915	3,837,865	87,306	5,975,592	64,307	19,206,521	899,819
1916	3,003,065	78,963	10,468,001	103,081	98,119,695	5,128,200
1917	5,344,334	132,572	11,760,935	136,064	162,734,010	11,410,606
1918	1,433,349	111,818	78,370	1,261	343,758,948	39,309,261
1919	4,368,780	201,496	16,988,787	483,221	195,808,421	24,019,226
1920	3,136,850	180,759	29,473,132	645,267	112,549,075	13,767,917

It is not expected that the soybean industry will develop in the near future to the extent attained in Manchuria. This industry should however, develop gradually and the soybean become an important crop in the regions most favorably situated for seed production, especially the cotton belt and the southern part of the Corn Belt. This crop offers an excellent opportunity to the Southern planter to adjust the plantation management so that he can offset the boll weevil damage and with profit to himself furnish the cotton oil owners a source of oil and meal.

The soybean is already a crop of high value in American agriculture and seems destined to be of far greater importance, not only as a cash crop, but as an aid in maintaining the productivity of the soil. It seems quite probable that the largest use of the crop except the oil will be primarily for forage. With a better understanding of the soybean and it's products, the industry should become a most important one.

Other Countries.—The trade in soybeans will undoubtedly be confined mainly to China, Japan, United States and Europe. When the trade in soybeans began to expand rapidly in Europe and America and the demand increased for vegetable oils, English firms began to consider the African countries as a source of

[1] Compiled from reports of Department of Commerce, Bureaus of Foreign and Domestic Commerce and Navigation, U. S. 1910–1920.

[2] Includes bean cake or bean stick, miso, or similar products, with duty, 40 per cent.

supply for these seeds. Extensive investigations were made on all Governmental Experimental farms in Africa and it was found that with a demand for soybeans at the prices prevailing in 1910, the colonies could compete very successfully with the importations from Manchuria. Although the soybean has been grown for a very considerable length of time in India, it has been used principally as a food by the natives and as a forage crop. Considerable experimental work has been done by the experiment stations situated in various parts, relative to the utilization of the bean as an oil seed, and it's further use for human food. India, however, has not made any attempts to concern itself in the world's trade with the soybean and its products.

In Australia, experiments have been carried on in Victoria and Queensland relative to the growing of the crop as an oil seed. The results reported would indicate that the soybean can be grown successfully for seed in these provinces and that Australia would be able to enter into the world's trade as a source of supply of soybean seed.

Summary of Imports and Exports of Soybeans and Soybean Oil.—Tables XIV, XV, XVI, and XVII summarize the imports and exports of soybeans and soybean oil in the World's trade for the years 1910 to 1919 inclusive.

Table XIV.—Quantity of Imports of Soybeans in the World's Trade,[1] 1910–1919 Inclusive

	1919, tons	1918, tons	1917, tons	1916, tons	1915, tons	1914, tons	1913, tons	1912, tons	1911, tons	1910, tons
Denmark	28,681.7	....	15,547.7	49,498.1	52,373.9	37,317.3	24,034.4	16,990.5	17,832.9	10,005.8
France	....	37.2	1,291.6	668.4	77.7	....	22.4	8.4	6.3	3.2
Norway	....	....	....	....	....	....	....	....	275.4	403.5
Holland	16,365.2	....	1,976.9	2,194.5	8,275.5	9,809.3	13,777.1	21,526.7	13,209.7	
Russia	....	....	....	....	2,274.5	2,849.1	1,930.4	2,251.0	1,852.0	1,791.8
United States	2,184.3	716.6	2,672.1	1,501.5	1,918.9	964.7				
Sweden	....	....	....	....	....	....	....	....	12.1	12.1
Great Britain	31,276.4	....	12,713.3	33,206.4	86,821.3	36,151.4	38,839.4	95,894.5	112,861.0	214,147.6
British E. Indies, Java & Manchuria	3,557.0	11,763.5	12,114.5	13,419.5	28,580.4	23,833.3	25,247.1			
Exterior possessions	1,125.0	1,452.7	1,539.5	1,634.1	1,458.8	1,455.7	1,473.1			
Japan	85,651.8	58,086.6	47,097.1	36,603.0	59,411.9	75,482.3	53,415.5	64,862.6	88,021.5	79,099.7
Formosa	....	....	227.4	944.7	3,559.0	2,828.8	2,894.0	1,801.2	481.6	364.9

[1] International Institute of Agriculture, Bureau of Statistics, 1921, pp. 368–369.

Table XV.—Quantity of Imports of Soybean Oil in the World's Trade 1910–1919 Inclusive[1]

Country	1919, tons	1918, tons	1917, tons	1916, tons	1915, tons	1914, tons	1913, tons	1912, tons	1911, tons	1910, tons
Germany	....	....	....	....	....	1,063.7	3,215.1	8,211.8	10,127.3	5,806.3
Denmark	....	....	....	2.3	20.8	18.0	....	10.9	146.0	150.1
Great Britain	15,079.6	302.8	1,779.1							
Holland	19,217.3	1,534.5	4,820.7	5,297.0	9,653.2	5,088.0	1,436.9	2,315.5	3,169.8	
Russia	....	....	....	....	2,274.5	2,849.3	1,930.4	1,581.4	2,251.0	1,852.0
Sweden	6,922.4	64.3	19.5	3,400.4	4,399.1	2,440.8	2,115.2	1,656.9		
Canada	2,774.3	4,580.1	4,686.1	2,502.5	1,216.2	961.2	863.4	1,033.1	829.2	699.4
United States	44,408.3	76,199.5	60,083.8	32,978.1	4,838.7	2,847.4	3,225.3	5,660.5	2,560.0	
Japan	837.5	597.3	232.3	249.1	689.0	727.7	1,417.3	2,068.7	357.2	0.3
Formosa	....	....	155.8	152.0	178.0	8.4	37.4	22.8	11.6	22.3

[1] International Institute of Agriculture, Bureau of Statistics, 1921, pp. 420–421.

TABLE XVI.—QUANTITY OF EXPORTS OF SOYBEAN OIL IN THE WORLD'S TRADE, 1910–1919 INCLUSIVE[1]

Country	1919, tons	1918, tons	1917, tons	1916, tons	1915, tons	1914, tons	1913, tons	1912, tons	1911, tons	1910, tons
Denmark	1,727.1	33.2	1,971.4	155.5	3,063.6	3,529.9	1,939.9	752.1	642.9	330.4
France	7.3	0.4	11.7	4.4	....	....	....	3.1	4.3	
Great Britain	527.8	....	308.9	2,313.5	6,844.6	4,735.3	4,770.3	8,802.5	10,407.3	
China	71,383.9	68,830.8	57,169.0	47,323.8	30,768.2	38,361.9	14,865.9	15,889.7	21,568.0	17,248.8
Japan	876.0	1,473.4	1,657.4	1,774.0	536.9	539.3	426.3	2,546.3	1,940.0	

[1] International Institute of Agriculture, Bureau of Statistics, 1921, pp. 420–421.

TABLE XVII.—QUANTITY OF EXPORTS OF SOYBEANS IN THE WORLD'S TRADE 1910–1919 INCLUSIVE[1]

Country	1919, tons	1918, tons	1917, tons	1916, tons	1915, tons	1914, tons	1913, tons	1912, tons	1911, tons	1910, tons
France	6.3	0.5	....	....	....	....	4.6			
England[2]	....	....	....	1,310.2	857.0	4,771.3	407.9	825.5	1,452.4	4,198.3
Holland	....	....	....	....	64.4	7,018.3	7,211.0	8,272.3	5,997.3	
China	500,775.0	267,078.6	302,502.4	115,766.3	354,851.0	337,397.2	312,057.0	330,502.0	333,650.4	330,238.1
Japan	330.3	361.7	766.5	385.9	237.6	220.2				
Formosa	....	....	....	....	2.3	....	1.0	4.9	2.4	13.3

[1] Reexportation.

[2] International Institute of Agriculture, Bureau of Statistics, 1921, pp. 368–369.

CHAPTER III

BOTANICAL HISTORY OF THE SOYBEAN

Few plants have had so involved a botanical history as has the soybean. This was largely due to other plants imperfectly described being confused with the soybean by the early botanists, and partly to the changing of the scientific name necessitated as knowledge increased. The complexities can be appreciated only by tracing the scientific history of the soybean in detail.

History Prior to Linnæus "Species Plantarum," 1753.—The soybean was first made known to Europeans by Engelbert Kæmpfer (1712), a German botanist who spent the two years 1691 and 1692 in Japan. Kæmpfer uses the Japanese name "Daidsu" and describes the plant as erect and bean-like, with pods like the lupine and seeds resembling large white peas. He also gives an excellent illustration of the plant and discusses in detail the various food products prepared from the bean by the Japanese.

Paul Hermann (1726), collected plants in Ceylon, which were very briefly described under the native names in a book called "Musæum Zeylanicum" published in 1717. One of these plants was called "Bumum" or "Buncæ" and is very briefly described as a species of bean with villose hairs. Hermann's original specimens are still preserved. One of them numbered 280, is also represented by a beautiful and accurate drawing. This plant is probably Hermann's "Buncæ." At any rate it is the soybean. The name "Bume" is at the present time used in Ceylon for the mung bean, so that it is probable that Hermann's name "Bumum" refers to the same plant and that he erroneously associated it with "Buncæ" which is the soybean.

Linnæus (1737) published a book called "Hortus Cliffortianus" based on plants cultivated in Clifford's garden at Hartecamp, Holland. One of the plants described was the soybean, as proven by the original specimens which still exist.

The fourth earliest description of the soybean was by Rumphius (1747), a Dutch naturalist who described and illustrated the plants of Amboina and other islands of the Dutch East Indies, in a book called "Herbarium Amboinense" published in 1747. His description and illustration of the plant called "Cadelium"

is very clearly the soybean. Rumphius gives the native name as "Kadelee" and states that the plant is rarely seen in Amboina but more abundantly in Java, Bali and other Malayan Islands.

These four descriptions are often referred to by later botanical writers whose interpretations were not always correct, so that much confusion of names occurred in later botanical literature.

Linnæus' Misunderstandings of the Soybean.—Scientific botanical names begin with the publication of Linnæus' Species Plantarum in 1753. The reason for this is because Linnæus reduced all plant names to binomials, that is composed of two words, while those of previous writers were mostly composed of several or many words. At the time of this publication, it appears therefore that the soybean had been described by Kæmpfer from Japan, by Hermann from Ceylon, by Rumphius from the East Indies and by Linnæus from a plant grown in Clifford's garden. Both Rumphius and Linnæus, however, cited descriptions of still other writers which they mistakenly assumed related to the same plant.

The actual confusion which took place was mainly due to an error in Linnæus. In the first edition of the Species Plantarum (1753) he describes two supposedly different plants, the first on page 725, the second on page 727. The first he called *Phaseolus max*, the second *Dolichos soja*. He had in his herbarium specimens of *Phaseolus max* from Clifford's garden, but his description of *Dolichos soja* was purely a compilation from other writers. To understand the confusion that this gave rise to, it is best to follow first the story of *Dolichos soja*. Linnæus' original description is as follows:

Dolichos soja.

> "Dolichos caule erecto flexuoso, racemis axillaribus erectis, leguminibus pendulis hispidis subdispermis. Fl. Zeyl. 534. Mat. med. 363.
>
> "Phaseolus erectus, siliquis lupini, fructu pisi majoris candido. Kæmpf. amoen. 837. t. 838.
>
> "Habitat in India."

This may be rendered in English as follows:

> "Dolichos with erect flexuous stem; racemes axillary, erect; pods pendent, hispid, mostly 2-seeded.
>
> "Erect bean with pods like those of lupine and seed like a large white pea.
>
> "Native country, India."

The description is so brief that without further evidence it would be practically impossible to identify the plant. Such evidence is secured partly from the older books which Linnæus cites and partly from preserved specimens.

Under Dolichos soja, Linnæus cites first "Fl. Zeyl. 534." This reference is to the "Flora Zeylanica" of Linnæus, published in 1747, and based primarily on Hermann's notes and specimens. The description there published is only slightly different from that in the "Species Plantarum" and is as follows:

> "Dolichos caule erecto flexuoso, racemis axillaribus erectis, leguminibus pendulis hispidis subdispermis.
> "Phaseolus erectus, siliquis lupini, fructu pisi majoris candido, Kæmpf. amoen. 837. t. 838.
> "Soja officinarum. Dal. pharm. 238.
> "Obs. Habitat in zeylona culta."

From this description it is evident that Linnæus had primarily in mind the plant cultivated in Ceylon and collected by Hermann, whose specimen still exists and is the soybean. The Kæmpfer reference also pertains to the soybean.

The name "soja" used in Japan for the soybean was not mentioned by Kæmpfer but Linnæus was already familiar with it, as he had referred to it in his "Materia Medica" published in 1749. Linnæus indeed cites Dale's Pharmacolgiæ (1751) p. 238, the first edition of which was published in 1705, at which date European pharmacologists were already familiar with the Japanese soybean and its medicinal uses. Dale calls it *Soia officinarum* and doubtless Linnæus got the name *soja* from this author.

In regard to *Phaseolus max* Linnæus, much doubt has existed as to its identity, which has recently been cleared up by a careful study of Linnæus" original specimen still preserved. The original description of Phaseolus max is as follows:

> "11. Phaseolus caule erecto anguloso hispido, leguminibus pendulis hirtis. Hort. cliff. 499. Roy. lugdb. 367. Fl. Zeyl. 280.
> Phaseolus orthocaulis, Mungo persarum, Hern. mex. 887. Habitat in India."

It will be noted that the first citation under the brief description refers to the Hortus Cliffortianus, a work published by Linnæus in 1737. The description in this book is as follows:

"3. Phaseolus caule recto anguloso hispido.
Phaseolus erectus, caule & folio rigidis, flore pallide luteo, siliqua crassa & ampla. Boerh. ind. 152.
Phaseolus ortocaulis, Mungo persarum, turcarum Masc, hispanorum Max. Hern. mex. 887. Boerh. lugdb. 2, p. 28.
Crescit in Virginia, unde e seminibus delatis prodiit."

This description differs somewhat from that of 1753, particularly in that the seed was supposedly from Virginia. This is doubtless an error, and it will be observed that Linnæus makes no mention of Virginia in his later description. The other citations in the 1753 description are:

"Roy. lugdb. 367." and "Fl. Zeyl. 280."

The first is to Royen's "Florae Leydensis Prodromus," where the description is exactly as in the "Hortus Cliffortianus," while the latter citation is to Linnæus' "Flora Zeylanica," containing a description based on Hermann's plant from Ceylon.

It is thus perfectly clear that the first part of Linnæus' description of *Phaseolus max* and the first three citations all refer to the soybean, but from Sir David Prain's (1897) careful study of the matter it would appear that Linnæus really intended the name *Phaseolus max* to apply to the mung bean of India. Linnæus repeated the description of *Phaseolus max* in the second edition of the Species Plantarum, published in 1763 but dropped it entirely in the third edition published in 1767 without any word of explanation. In 1767, however, he describes fully the mung bean under the name *Phaseolus mungo*.

Prain's Elucidation.—Prain's explanation of how Linnæus was led into the error of confusing under one name two plants as different as the soybean and the mung bean is very interesting.

"What Linnæus meant by *P. max*, as contrasted with what he named *P. max*, we reach if we follow the clue afforded by his citation 'Phaseolus orthocaulis, Mungo persarum, Hern. Mex. (1651), 887. When we turn to the passage indicated we find (1) that the actual phrase is 'Mungo, sive Phaseolus orthocaulis' so that the citation is incorrect; (2) that the article begins: 'Mungo, apud Indos orientales a Persis, ac etiam a Turcis dicitur Masc quod ab Hispanis diceretur Max.,' so that the expression 'Mungo persarum' reverses what is actually said; (3) that the names 'Mungo' 'Masc' and 'Max' are not employed by Hernandez at all because they occur in the separate treatise termed 'Annotationes et Additiones' written by Fabio Colonna. The article on 'Mungo' is one of the 'Additiones' not a mere 'Annotatio' so that it is attributable to Colonna alone.

"Clearly then Linnæus got his expression 'Mungo persarum elsewhere and clearly the place whence he took it was Boerhaave's Ind. Alt. Lugds. Bat. 11, p. 28 (1720) where we find recorded: '16 Phaseolus; octocaulis; Mungo Persarum; Turcorum Masc; Hispanorum Max. *Fab. Col. Annot. et. Addit. in Nard. Ant. Recch.* p. 887.' Here we find a misreading of the name 'orthocaulis,' which Linnæus avoided, with a correct citation of authority which Linnæus did not choose to follow. The interesting feature of this citation is that it supplies us with the source of the specific epithet *Max* and of the erroneous expression 'Mungo persarum' wrongly attributed to Hernandez (1651).

"The punctuation in Colonna's passage is certainly singularly inept but the concords are unimpeachable and afford as little excuse for the misleading paraphrase of Colonna's statement as there is for the misreading of the name 'orthocaulis.'

"Colonna's article deserves more careful consideration than it has hitherto been given. After supplying a fair description of the plant intended, and a rough figure which suits best the plant that is *P. max* Roxburgh, not at all of Linnæus, Colonna describes the germination of the seeds in a fashion that leads one to believe him to be describing what he has seen with his own eyes.

"But the principal points to be noted are that Colonna does not say the plant is a Mexican one; he does not quote for it any Mexican name. On the contrary he uses for it two Asiatic names with the Spanish (or Portuguese) variant of one of them and still further shows his acquaintance with the fact that it is an old world species by giving a Latin version of what Garcia del Huerto had to say about the same Indian plant. We see from this version that Colonna went to Garcia's original text and did not quote from Clusius's Latin translation of Garcia issued in 1567.

"There is no reason why by 1651 the mung should not have been introduced as a food for horses into Mexico. But there is also no proof that the article was intended by Colonna as more than a suggestion to the Spaniards that a horse-food so useful as this was known to be in India, might with advantage be introduced into Mexico."

This discovery that the name *Phaseolus max* really belongs with the soybean made it necessary to revise the scientific name of the latter. To quote again from Prain;

"As regards *P. mungo* L. the fact remains that, whatever may have been the origin of the plant he describes, no specimen appears ever to have been added by Linnæus to his herbarium and all that we are justified, by the evidence available, in assuming is that Linnæus, in 1767, as already in 1753 deemed *Mungo* the precise equivalent of *Max.* If this be so, it may very fairly be asked why, in 1753, did Linnæus use *Max* in preference to *Mungo* and why in 1767 did he drop *Max* and use *Mungo* instead?

"The answer in both cases seems to me self evident. Of the two synonyms *Mungo* and *Max*, clearly *Max* was the oldest because *Mungo* occurs for the first time in Garcia del Huerto while *Max* goes back to Avicenna. Linnæus chose *Max* because of its greater age.

"In the other case Linnæus in all good faith supposed that 'Buncæ' of Hermann and the plant he saw in Clifford's Garden were the same thing as Mungo and Max, at the time he wrote the Flora Zeylanica. He had no suspicion that the plant he had described was different from the plant whose name he had adopted when he published the first edition of the Species Plantarum in 1753. He was still unconscious of the extraordinary blunder he had committed when he published the second edition in 1763. But some time after he had published the second edition of the Species Plantarum he obtained from some one seeds of the plant he had described in 1753 as *Dolichos Soja.* He raised plants from these seeds at Upsala and put specimens into his herbarium some time before 1767 when he for the first time recorded its existence in his collection.

"Linnæus was at last in a position to see that the plant he had described as *Phaseolus max* was the same as the one he had named *Dolichos Soja* and that the Mung crop (Mungo or Max) was still without a name. It may be that in putting matters right Linnæus felt that to continue for the 'Mungo' or 'Max' crop the name *Max* might lead to confusion and that to obviate this confusion it was desirable to substitute the other name *Mungo.*

"As a merely bibliographical matter then the decision of Trimen (1894) to revert to the name *P. max* (1753) which was intended to signify the same species as the *P. mungo* of 1767 had apparently full justification. But it does not seem desirable to follow Trimen owing to the fact that, though *P. max* was intended to signify the Mung crop, in reality the plant described and represented by the Linnæan types is the 'Soy' crop."

Other Botanical Names.—Moench (1794) rechristened the Linnaean plant *Soja hispida.* Savi (1824) called the Japanese soybean *Soja japonica.* Miquel (1855) named a narrow-leafed form from Java *Soja angustifolia,* and Maximowicz (1873) using Moench's specific name, published the soybean as *Glycine hispida,* which name has been adopted by many authors. Siebold & Zuccarini (1843) had previously named a plant from Japan *Glycine soja,* supposing it to be the *Dolichos soja* of Linnæus. This plant, however, was not the soybean cultivated by the Japanese but the wild plant (Fig. 9) later described as *Glycine ussuriensis* by Regel & Maack (1861). By most writers the soybean, which is known only as cultivated, has been called *Glycine hispida* (Moench) Maximowicz, and its nearest relative *Glycine soja* Siebold & Zuccarini (*G. ussuriensis* Regel & Maack).

Maximowicz (1873) considered that the cultivated soybean was probably derived from *Glycine ussuriensis* Regel & Maack; Franchet & Savatier (1875) express the same opinion. This view was not adopted by most botanists but the recent work of Piper & Morse (1910) leaves scarcely room to doubt that Maximowicz's opinion is correct as every possible form between the wild soybean and the cultivated soybean occurs.

The Correct Botanical Name.—Inasmuch as the specific name *max* as applied to the soybean appears on a previous page to the name *soja* in Linnæus' Species Plantarum, it has priority according to all botanical codes and hence must be adopted as the specific botanical name of the soybean.

In most botanical works the soybean is called *Glycine hispida* (Moench) Maximowicz. By a few writers it is named *Soja hispida* Moench. The use of either of these names is based on the idea that the wild soybean *Glycine soja* Siebold & Zuccarini or *Glycine ussuriensis* Regel & Maack is a different species. As Piper & Morse (1910) have shown, this view is untenable, the wild and the cultivated plants representing but one species. The cultivated plant was first named *Dolichos soja* L. but as the specific name *soja* was used later by Siebold & Zuccarini for the wild plant, it has since been generally used in that sense. With the recognition of the fact that there is but one species and not two the name *Glycine soja* (L.) Siebold & Zuccarini designates the cultivated as well as the wild plant. But the specific name *soja* must now give way to that of *max*.

Unfortunately there is also question as to the proper generic name to be attached to the soybean. Nearly all botanists have used the name *Glycine* for the genus containing the soybean and related species, but a few have used *Soja*. Soja was proposed by Moench (1794) and included only the soybean.

Linnæus in using the name *Glycine* in the Species Plantarum (1753) cites *Apios* of Boerhaave as a synonym. He describes 8 species as follows:

1. Apios = Apios tuberosa
2. Frutescens = Kraunhia frutescens.
3. Abrus = Abrus precatorius.
4. Tomentosa = Rhynchosia tomentosa.
5. Comosa = Amphicarpaea comosa.
6. Javanica = Glycine javanica.
7. Bracteata = Amphicarpaea bracteata.
8. Bituminosa = Fagelia bituminosa.

As will be seen all of the original species of *Glycine* have been removed from the genus but one, *Glycine javanica,* which by the method of elimination would be the type species of the genus *Glycine.* While in this particular case the method of elimination works very nicely, there are numerous other cases in which it leads into hopeless difficulties.

Inasmuch as Linnaeus cites *Apios* of Boerhaave as a synonym of *Glycine,* some recent botanists have considered that *Glycine* should be used in that sense and hence have employed it in preference to *Apios* for the plant described by Boerhaave, namely, the American wild bean or groundnut. This seems clearly to have been the idea in Linnæus' mind. If *Glycine* be thus used the next available name for the soybean genus is *Soja* of Moench, published in 1794. Following this interpretation the soybean must be named *Soja max* (L.) Piper (1914). Other botanists consider *Glycine javanica* the type species of the genus and call the soybean *Glycine max* (L.) Merrill.

It is a queer outcome of the application of botanical rules that the accepted scientific name must perpetuate the blunder that Linnæus made, and which necessitates using a common oriental name for the mung bean as the specific title of the soybean. The complete binomial synonomy of the soybean is as follows:

Phaseolus max L. Sp. Pl. 2: 725. 1753.

Dolichos Soja L. Sp. Pl. 2: 727. 1753.

Soja hispida Moench. Meth. 153. 1794.

Soja japonica Savi in Pisa Nuov. Giorn. Litt. 8: 113. 1824; and Mem. Phas. 2: 16. 1824.

Glycine soja Siebold & Zuccarini in Abh. Akad. Muench. 42: 119. 1845.

Soja angustifolia Miquel Fl. Ind. Bat. 1: 223. 1855.

Glycine ussuriensis Regel & Maack. in Tent. Fl. Ussur. 50. 1861.

Soja max Piper. Journ. Amer. Soc. Agron. 6: 84. 1914.

Glycine max Merrill, Publ. 9. Dept. Agr Bur. Sci., Manila. 274. 1917.

CHAPTER IV

AGRICULTURAL HISTORY OF THE SOYBEAN

Like most important food plants, the early history of the soybean is lost in obscurity. Doubtless it was utilized, if not cultivated, by primitive man long before the dawn of historical records. Such history as does exist, however, bespeaks a very ancient culture. Over fifty different names are used in oriental countries for the soybean, and doubtless there are many more. This great number of appellations is an evidence of long culture.

VERNACULAR NAMES OF THE SOYBEAN

Name	Locality
An-ing	Naga Hills, Assam
Bhat	United Provinces, India
Bhatmas	United Provinces, India
Bhatnas or Bhatwas	Nepal
Bhatwan	Ceylon
Bhatwas	United Provinces, India; Nepal
Bhetmas	Bengal, India
Bhut	Punjab, India
Botumash, Bhativas or Bhatmais	Buthia, India
Buncæ	Ceylon
Cadelee	Amboina
Chlai	Bengal, India
Coffee Bean	United States
Dâŭ nanh	Annam; Cochin China; Tonkin
Dâŭ tuong	Tonkin, French Indo-China
Daidzu	Japan; Tonkin
Disomhorac	Santhal, India
Gari-kalai	Bengal, India
Hoam teŭ	Cochin China
Japan pea	United States
Kajuna	Nepal
Kajang koro	Celebes
Katjang-boeloe	Java; Sŭnda
Katjang-djepoen	Java; Sŭnda
Katyang kadeleh	India
Khujoon	N. W. Provinces, India
Kije	Naga Hills, Assam

Name	Location
Lasi	Kachin, Burma
Lasi shapre turu	Bhamo, Burma
Lasi N'Loi	Myitkyina, Burma
Lasi N'Hti	Myitkyina, Burma
Mame	Japan
Patani	India
Patani-jokra	Assam
Pe-kyat-pyin	Burma
Pe-nga-pi	Burma
Pois oleagineux de Chine	France
Ram kurthi	Bengal, India
Ryambai-ktung	Khasi Hills, Burma
Salyang (Selliyang)	Sikkim
San-dek-sieng	Cambodia, French Indo-China
Sandek an gen sar	Cambodia
Silliangdun	Sikkim
Soia	France; Italy
Soja	France; United States
Sojaboon	Holland
Sojabohn	Germany
Sou	China
Soy	United States
Soya	United States; England
Stock pea	United States
Sudza	Naga Hills, Assam
Ta teou	China
Teou	Tonkin
Tzuda	Naga Hills, Assam
Yeou	China

China, Korea and Japan.—The soybean is a plant of very early cultivation in China. According to Li-Yu-Ying and Grandvoinnet (1911–1912) the soybean is described in the book of Materia Medica "She-non" written over 5,000 years ago. The celebrated dictionary of Sui Sham describes the plant under the name of "*tchoŭan*." In another ancient dictionary, the "Kouang-ia," dating from about the time of the Christian Era, the soybean is called *ta-teoŭ* or grand pea and also *sou*. It seems very probable that the names soi, soy, soya and soja are all derived from the ancient Chinese name sou.

In Manchuria the soybean is grown to a greater extent than in any other country, and its culture there is doubtless ancient. From Korea, there have been sent to the United States Department of Agriculture many distinct varieties, the large number indicating long cultivation in that country. The culture of the

soybean in Japan is likewise very old and many varieties peculiar to that country are in cultivation.

No comprehensive account of the agricultural history of the soybean in any of these countries has yet been attempted, but doubtless much information is contained in ancient Chinese and Japanese literature.

Several varieties different from any secured elsewhere have been introduced into the United States from Formosa, and the plant has probably been cultivated there for a considerable period.

India and Neighboring Regions.—Southward from China the soybean is largely a crop of the hilly regions. De Candolle (1884) believed that the plant was a recent introduction in India, mainly because Roxburgh had not encountered the plant except as he had cultivated it in the Calcutta Botanic Gardens. The recent investigations of Hooper (1911, 1912) and of Woodhouse and Taylor (1913) together with other information, show, however, that the soybean is widely if not abundantly cultivated, especially in the hilly regions of India from the borders of Afghanistan eastward to Burma; indeed its culture also extends to northern Siam and French Indo-China.

Hooper records seeds from many Indian sources, aggregating perhaps nine distinct varieties. Most of these were later sent to the United States Department of Agriculture and grown at Arlington. Virginia, and elsewhere in comparative trials. The data show the following facts as to origin and varieties:

Small yellow from Haka, Chin Hills, Burma and Kalimpong, Darjeeling.

Smaller yellow from Simla, Punjab; Chakrata, Dehra Dun; Kalimpong, Darjeeling; Tiddim, Chin Hills, Burma; and Katha, Burma.

Smallest yellow mainly from Burma.

Small black "largely grown in various districts of the United Provinces and Patna Division, as well as on the lower slopes of the Himalayas from Kashmir to Darjeeling."

Large brown from Darjeeling.

Small brown "grown in the Himalayas from Kashmir to Darjeeling."

Mottled yellow and brown from Shillong, Burma.

Besides the above Hooper records several varieties of Chinese origin cultivated at Poona, Bombay.

Woodhouse and Taylor describe nine Indian varieties secured from Darjeeling, Bankipur and Bhagalpur.

FIG. 8.—Plants of a soybean variety from India.

Major T. E. T. Aitchison (1881) found the soybean largely cultivated in the Kuram Valley, Northwest Frontier Province,

FIG. 9.—Plants of the wild soybean from Soochow, China, grown at the Arlington Experimental Farm, 1908.

India, especially in the Kuram district, occasionally in Hariab; also frequent as a weed in cultivated ground.

Most of the Indian varieties (Fig. 8) have slender twining

stems, small pods and small seeds. They resemble the wild soybean (Fig. 9) much more closely than do the varieties of China and Japan. All of the facts indicate the long culture of the soybean in northern India and Burma.

Cochin-China.—In Cochin-China the soybean is cultivated to some extent. Louriero (1793) records the soybean as cultivated under the names *Dâŭ nanh* and *Hoam teŭ*. These notes probably refer to the neighborhood of Hue, where most of Louriero's work was done. Pierre (1869) states that it is grown at the present day about Saigon, and from this place the United States Department of Agriculture secured a very late yellow-seeded variety, No. 22714.

Malayan Region.—In the islands south of the Asiatic mainland, the soybean is not a crop of much importance. Its culture or occurrence in Ceylon was recorded by Hermann in 1726; in Amboina by Rumphius in 1747, in Java near Bandong by Miquel in 1855, and on Mount Gunung-Gamping by Junghuhn (1853). Seed of one variety was received by the United States Department of Agriculture in 1900, from Macassar, Celebes.

Pierre (1869) states, but without particulars, that the plant is cultivated in Borneo and the Philippines, but it has not been found cultivated by the natives of the latter country since the time of the American occupation, though doubtless occasionally grown by the Chinese.

Early Introduction into the United States.—There are fortunately fairly complete records of the early history of the soybean in the United States. The facts emphasize the difficulties with which a new crop wins its way to recognition.

The Earliest Records.—The first mention of the soybean in American literature is by Mease (1804), who writes "The soybean bears the climate of Pennsylvania very well. The bean ought therefore to be cultivated."

Thomas Nuttall (1829), grew a variety with red flowers and chocolate-brown seeds in the botanic garden at Cambridge, Mass., and from his observations wrote a brief account concerning it. He writes:

"Its principal recommendation at present is only as a luxury, affording the well-known sauce, soy, which at this time is only prepared in China and Japan."

In the same journal two years later, November 23, 1831, is an account of the successful culture of the plant at Milton, Mass., the seed having been obtained from Nuttall.

No further mention of the plant in American literature appears until 1853, when a brief account appeared under the name "Japan pea" by Ernst (1853), as follows:

"The Japan pea, in which so much interest has been manifested in this country for a year or two past, from its hardihood to resist drought and frost, together with its enormous yield, appears to be highly worthy of the attention of agriculturists.

This plant is stated to be of Japan origin, having been brought to San Francisco about three years since, and thence into Illinois and Ohio. Its habit of growth is bushy, upright, woody, and stiff, branching near the ground, and attaining a height of three or four feet. The leaflets are large, resembling those of an ordinary bean, occurring in sets of three, with long quadrangular stems. The flowers, which are small and white, but rather inconspicuous, sometimes having purple centers."

The Perry Expedition to Japan.—The Perry expedition in the year 1854 brought back two varieties of "soja bean" from Japan, one "white" seeded, the other "red" seeded. These, together with the Japan pea, were distributed by the Commissioner of Patents in 1854, (Browne 1854) and, thereafter frequent references to the plant occur in agricultural literature under such names as Japan pea, Japan bean, and Japanese fodder plant. Most of these articles speak of the plant as the Japan pea, none of them as the soy or soja bean. It is apparent from the early accounts that there were at least two Japan peas, one early enough to mature in Connecticut (Patent Office Report, 1854, p. 194), the other very late (American Agriculturist, 1857, vol. 16, p. 10). Judging from all the accounts, we suspect that the early Japan pea may be the Ito San variety, which, however, has red flowers, while the late variety may be the Mammoth. The Ito San is still occasionally called the Japan pea, while the introduction and source of the Mammoth has never been definitely determined. From these early accounts the Mammoth may well be the "white-seeded" soja bean obtained by the Perry expedition. The "red-seeded soja bean" was, probably, the adsuki bean (*Phaseolus angularis*), as no red-seeded soybean is known.

Later Introductions.—Prof. G. H. Cook, of New Brunswick, N. J., obtained seed of the soybean at the Bavarian Agricultural Station in 1878. In the same year Mr. James Neilson obtained seeds of several varieties at Vienna, Austria. Both of these

gentlemen planted the seeds and gathered crops of the different varieties in 1879. These varieties were without doubt some of those grown and distributed through Europe by Professor Haberlandt of Vienna.

A yellow-seeded soybean was grown at the North Carolina Agricultural Experiment Station in 1882 and reported on in some detail. The source of the variety is not given, but by implication it is the same as the variety stated to be grown by a number of persons in the State, and is probably the Mammoth.

Two varieties, one black seeded, the other with white seeds, were grown at the Massachusetts Agricultural Experiment Station in 1888.

In 1890 Prof. C. C. Georgeson (1890) secured three lots of soybeans from Japan which were grown at the Kansas Agricultural Experiment Station in 1890 and subsequently.

Prof. W. P. Brooks, (1890) of Amherst, Mass., brought with him from Japan in 1889 a number of soybean varieties, including the Medium Green or Guelph, and the Ito San. It is quite certain that other importations of soybeans from Asia were made by others, but no definite records have been found.

Since 1890 most of the agricultural experiment stations have experimented with soybeans and many bulletins have been published dealing wholly or partly with the crop.

The Early Introduced Varieties.—Previous to the numerous introductions by the United States Department of Agriculture beginning in 1898, there were not more than eight varieties of soybeans grown in the United States, namely, Ito San, Mammoth, and Butterball, with yellow seeds; Buckshot and Kingston, with black seeds; Guelph or Medium Green, with green seeds; and Eda and Ogemaw, with brown seeds.

It has been possible to determine the history of these, in part at least, which is of value in interpreting the older records.

Ito San.—Ito San was among the varieties introduced in 1899 by Prof. W. P. Brooks, of Amherst, Mass., and by him called Early Yellow. Later E. E. Evans of Michigan secured seed of it and in 1902 called it Ito San. Mr. Evans writes that he subsequently secured it "from half a dozen sources in the United States and Japan." The same variety was also among those introduced by Prof. C. C. Georgeson, of the Kansas Agricultural Experiment Station, and grown in 1890 and subsequent years. This conclusion is based on the identity of nine

varieties obtained from the Rhode Island Agricultural Experiment Station in 1903. This station had previously obtained several varieties from the Kansas Agricultural Experiment Station in 1892. Three of the varieties from Rhode Island had exactly the same names as those published in Bulletins 19 and 32 of the Kansas Agricultural Experiment Station, namely, Eda Mame, Yellow Soybean, and Kiyusuki Daidzu. All three of these are Ito San.

Ball (1907) gives a list of numerous American sources through which this variety was secured under such names as Yellow, Early Yellow, and Early White. It was also grown at the Virginia Agricultural Experiment Station in 1905 as Japanese pea, as shown by later cultures at the Arlington Experimental Farm of seed from this experiment station.

Among the introductions of the Office of Foreign Seed and Plant Introduction it is represented by No. 6326, received in 1901 from Tokyo, Japan, and No. 21818, obtained from Vilmorin-Andrieux & Co. (1891), Paris, France, as "Yellow Etampes." It may possibly be one of the varieties grown by Professor Haberlandt in his experiments, as all of his varieties were grown at Etampes and other places in France. We suspect that this is also the variety that was distributed by the United States Patent Office in 1853, as most of the early accounts point to this or a closely similar variety. These accounts refer to it as Japan pea, Japanese pea, Japan bean, and also coffee berry.

Mammoth.—The Mammoth is at present the most important soybean grown in the United States. It has also been known as Late, Yellow, Late Yellow, Southern, and Mammoth Yellow.

The date of introduction of this variety is very obscure, and nothing definite is known regarding its origin. None of the numerous recent introductions are identical and but one is closely similar, namely, No. 22318, from Erfurt, Germany, received as "Yellow Riesen." It is not probable, though, that this was German-grown seed, as so late a variety could scarcely mature in Germany. Several varieties from Shanghai, China, and from Japan are closely related. It may possibly be the "white-seeded" soybean introduced by the Perry expedition. We have been unable to find any early published records that definitely refer to this variety. It is not improbable that it is this variety that was grown at the North Carolina Agricultural Experiment Station in 1882. There can be but little doubt that it is the

"soja" bean from T. W. Wood & Sons, Richmond, Va., grown by Georgeson (1890) at the Kansas Agricultural Experiment Station in 1889 and in 1890. Since 1895 Mammoth has been a well-known variety.

Buckshot.—The history of this variety is somewhat complicated. It has been obtained from the following American sources:

Agrostology No. 1184, "Black" from Rhode Island Agricultural Experimental Station, spring, 1903.

Agrostology No. 1301, "Early" from Johnson & Stokes, March, 1902.

Agrostology No. 1303, "Extra Early Black" from J. M. Thorburn & Co., March, 1902.

Agrostology No. 1304, from W. A. Burpee, March, 1902.

Agrostology No. 1474, "Extra Early Black" from Hammond Seed Company, March, 1903.

Agrostology No. 2033, "Crossbred No. 9" from the Arkansas Agricultural Experiment Station, May. 1904. "Crossbred No. 9" of Evans is really Ogemaw, while his "Crossbred No. 6" is Early Black or Buckshot. These two numbers were exactly reversed at the Arkansas Experiment Station, as the variety received from that station as "Crossbred No. 6" (Agrostology No. 2031) proved to be Ogemaw.

All of the foregoing were later united as S.P.I. No. 17251.

S.P.I. No. 6334, from Tokyo, Japan, April 20, 1901. Among the progeny of this are S. P. I. Nos. 8491, 9412, and probably 11179, and Agrostology No. 1292.

S.P.I. No. 19987, from Yokohama, Japan, 1907.

S.P.I. No. 22883, from Tokyo, Japan. 1908.

S.P.I. No. 22322, "Early Black from Podolia" Haage & Schmidt, 1908.

S.P.I. No. 25212A., from Botanic Gardens, Bremen, Germany.

From these data it would appear that the Buckshot is a common Japanese variety. But E. E. Evans, West Branch, Mich., claims that this variety was originated by him in 1901, as a hybrid, "Evans' Crossbred No. 6," which he advertised in 1902 and distributed widely. In recent correspondence Mr. Evans states that this was a hybrid of a large, flat, black variety, Medium Early Black, and of the Dwarf Brown. According to C. R. Ball, No. 6334 and its progeny numbers were identical with Evans' variety. In H. T. Nielsen's opinion Nos. 19987 and 22883 were also precisely identical. Unfortunately, these three Japanese lots were not grown in 1909. A critical comparison of the seed samples shows, however, that the three Japanese lots

have thicker, more nearly globose seeds than most of the lots derived from Evans' plant. It is, therefore, not unlikely that there are really two closely similar but distinct varieties involved. Nos. 22322 and 25212A are undoubtedly the same as Evans' plant.

Guelph, or *Medium Green*.—Guelph, or Medium Green, was introduced by Prof. W. P. Brooks, in 1889, from Japan, and is now quite extensively grown in the northern states. The same variety was also obtained from Hankow, China, in May, 1901—S.P.I. No. 6558, according to Ball's (1907) identification. It has since been received from only one foreign source, namely, S.P.I. No. 22320, from Haage & Schmidt, as "Green Samarow." This last might easily be the progeny of the American introduction.

Butterball.—The Butterball variety was first secured from the Rhode Island Agricultural Experimental Station in 1903 as "Early Japan" and it is probably one of Professor Brooks's introductions. According to Ball (1907), S.P.I. No. 8422, from Yokohama, Japan, is identical. A recent culture of this number obtained after a lapse of several years from the Illinois Agricultural Experiment Station, through H. B. Derr, proved to be Butterball, but there were a few different things intermixed, probably hybrids. A recent lot of seed from Dammann & Co., Naples, Italy, S.P.I. No. 22415, received as "Giant Yellow," is undoubtedly Butterball.

Kingston.—The Kingston soybean was received from the Rhode Island Agricultural Experiment Station in 1903 as "Japanese No. 15." It was obtained by them from Prof W. P. Brooks, of the Massachusetts Agricultural Experiment Station, who brought a number of soybean varieties from Japan in 1889, and is probably the variety which he named "Medium Black." It has never been secured from any other source. In all probability this is the variety grown at the Rhode Island Agricultural Experiment Station in 1893 as "Medium Black."

Samarow.—The Samarow has not occurred in any of our Asiatic importations. It is advertised under the name of "Green Samarow" by several European seedsmen. J. M. Thorburn & Co. who first introduced it into the United States about 1901, inform us that their seed was from Italy. The "Green Samarow" S.P.I. No. 22320, from Haage & Schmidt, Erfurt, Germany, proved to be Guelph.

Eda.—The Eda is the brown-seeded variety introduced from

Japan and grown by the Kansas Agricultural Experiment Station in 1890 under the name *Yamagata Cha-daidzu.* The identification of Cha-daidzu rests on the fact that the Rhode Island Agricultural Experiment Station secured all of the varieties from Kansas in 1892. The Department of Agriculture obtained all of these varieties from Rhode Island in 1903, including but one brown-seeded variety under the name "Brown Eda Mame."

Ogemaw, or *Ogema* —The Ogemaw, or Ogema, variety was first introduced by E. E. Evans, of West Branch, Mich., in 1902, as "Evans' Crossbred No. 9." Mr. Evans writes that he originated this as a cross between his No. 6, Early Black, and the Dwarf Brown. All of the several lots of this variety grown in our trials, namely, Agrostology Nos. 13502, 17258, and 17259 trace back to this origin, and it has been obtained from no foreign source. Nos. 21755, from France, and 25212 from Bremen, Germany, are very similar, however.

The Soybean in Europe.—The soybean has been grown experimentally at least in most of the European countries but in general the climatic conditions are not well suited to its culture. Some measure of success has been had however in south Europe, but the crop has never become of much importance.

France.—Paillieux (1880) has traced in detail the records of early attempts to introduce the culture of the soybean into France. Packets of soybean seeds from missionaries in China were received at the Jardin des Plantes, Paris, in 1739 and at frequent later dates beginning with 1834. The plants were very probably grown at the botanical garden since 1740, certainly so in 1779, and from 1834 to 1880 without interruption. In 1821, an unusually warm season, a Chinese variety had matured seed at Champ-Rond near Etampes. Beginning with 1855 the Societe d'Acclimatation distributed numerous packets of seed, but did not succeed in establishing a permanent culture of the plant. In 1868 M. Chauvin cultivated several varieties at Cote d'Or, and the culture there has since continued. In 1874 the Society of Horticulture of Etampes began experiments that continued until 1880. In 1879 a Chinese variety matured well at Marseilles. In 1880 Vilmorin-Andrieux & Company introduced into France one of the varieties tested by Haberlandt in Austria, which variety has proven well adapted to French conditions. This variety is presumably that now known in

France as "Yellow Etampes" which is the same as that known in the United States as "Ito San."

The soybean is now rather widely grown in France but apparently is not an important crop. No definite statistics of its culture seem to have been published. Presumably it is grown more as a garden vegetable than as a field crop. Apparently only four varieties were cultivated in France before 1910 namely: Yellow Etampes (=Ito San); Early Black from Podolia (= Chernie); Brown (= Ogemaw); and Extra Early Black (=Wisconsin Black). All of these are short season varieties, indicating that the later sorts will not mature in France.

Italy.—The cultivation of the soybean in Italy dates from about 1840. At the present time it is grown sparingly in the compartments of Liguria, Emilia, Marches, and near Naples. In no part of Italy does it seem to be a crop of prime importance.

Austria and Germany.—A great impetus was given to the culture of the soybean in Europe by the experiments of Prof. Friedrich Haberlandt (1878) of Vienna, in 1875 and subsequent years. Haberlandt obtained seed of nineteen varieties at the Vienna exposition in 1873. These were as follows:

Five yellow-seeded varieties from China.
Three black-seeded varieties from China.
Three green-seeded varieties from China.
Two brown-red-seeded varieties from China.
One yellow-seeded variety from Japan.
Three black-seeded varieties from Japan.
One black-seeded variety from Trans-Caucasia.
One green-seeded variety from Tunis.

Of these only four varieties matured at Vienna in 1875, namely, two yellow-seeded, one black-seeded and one brown-red-seeded, all from China. The black-seeded sort was so late that it matured but few seeds. Of the other varieties some did not even come into bloom, while the remainder produced blossoms or young pods too late in the fall to mature.

In 1876 the two yellow and the brown varieties were tested by cooperators in Hungary, Bohemia, Steirmark, Bukowina, Moravia, and Silesia, favorable results being secured in each case.

In 1877 seeds of all four varieties were distributed to 148 cooperators, mostly in Austria-Hungary, but some in Germany and Russian Poland, and one each in Switzerland and Holland. Most of the tests gave promising results.

Haberlandt (1878) published the results of his investigations in much detail, and his results had great influence in stimulating further investigations. All of the varieties that Haberlandt was able to mature were short season varieties, which in general are far less productive than later sorts.

England.—According to Aiton (1812) the soybean was grown as early as 1790 at the Royal Botanic Gardens, Kew, but merely as a botanical curiosity. The soybean has apparently never been grown as a crop in England, where indeed only the earliest varieties would be expected to mature.

Investigations on the adaptability of the soybean have been carried on by Dr. J. L. North of the Royal Botanic Gardens during recent years. Early varieties were introduced from numerous sources. With careful selections two or three quite promising early strains have been obtained which mature fully and give good yields of seed under English conditions.

The Varieties Grown in Europe and the Identifications of Those Grown by Haberlandt.—Seeds of soybeans were secured by the U. S. Department of Agriculture from various European sources, including five packets from Dr. E. Von Tschermak of Vienna, said to be the progeny of those used by Haberlandt in his experiments. These were tested one or more years at Arlington Farm, Virginia, and their identities established as follows:

Samarow.—Seed obtained from Dammann & Co., Naples, Italy, No. 22411, and identical with No. 17260, which last was introduced by Thorburn & Co. from Italy. Also No. 01597 from Von Tschermak, Vienna, said to be one of Haberlandt's varieties, but this is probably an error as Haberlandt mentions no green-seeded sort that matured in his experiments.

Etampes.—Seed from Vilmorin-Andrieux & Co., Paris, France, No. 21818, proved identical with Ito San. Also advertised by other Europeans, usually as Yellow Etampes.

Wisconsin Black.—Seed was received from Vilmorin-Andrieux & Co. as "Early Black from Podolia," No. 21757 and No. 21756; from Haage & Schmidt, Erfurt, Germany, as No. 22321; from Dammann & Co., as "Black," No. 22412; No. 01596 from Von Tschermak, Vienna, the "Black" of Haberlandt's experiments: and No. 5039 from Vilmorin-Andrieux & Co. as "Extra Early Black Seeded." This last is the original importation of the variety later named Wisconsin Black, S.P.I. No. 25468, which is now commercially handled by a few seedsmen.

"*Yellow Riesen.*"—Seed obtained from Haage & Schmidt, No. 22318. The variety is very similar to Mammoth, but somewhat later. No. 22317, "Yellow," from the same source, has indistinguishable seeds, but these did not germinate.

Buckshot.—No. 22322, obtained from Haage & Schmidt, is indistinguishable from the Buckshot variety, S.P.I. No. 17251. It was received as "Early Black from Podolia," but is not the same as the variety received under the name from another source. Seeds of this variety were also mixed in the brown seed from the Botanical Garden of Bremen, Germany, and grown as No. 25212A.

"*Yellow.*"—This variety was received from Dammann & Co., No. 22414, and Vilmorin-Andrieux & Co., No. 21754, the two being identical and different from any others yet received. It is a small, early variety, maturing at Arlington in ninety days. No. 17276, without name, from Havre, France, is a very similar but distinct variety, matched exactly by No. 01594 from Von Tschermak, Vienna, said to be the progeny of one of the yellows used in Haberlandt's experiments.

"*Brown.*"—Seed under this name was obtained from Dammann & Co., No. 22413, Haage & Schmidt, No. 22319, and Vilmorin-Andrieux & Co., No. 21755. These seeds are indistinguishable, but only No. 21755 grew. The original seed of this is much smaller than Ogemaw, but in 1909 both the seeds and plants could not be distinguished from Ogemaw from Michigan. No. 25212, from the Botanical Garden, Bremen, Germany, also with brown seeds, was likewise indistinguishable from Ogemaw in 1909, though the original seeds were different both from No. 21755 and from Ogemaw. Finally two lots of seed, Nos. 01595 and 01598, from Von Tschermak, Vienna, said to be the brown of Haberlandt's experiments, also proved to be Ogemaw.

Butterball.—The variety secured from Dammann & Co., No. 22415, as "Giant Yellow," could not be distinguished from S.P.I. No. 17274, Butterball.

There are no authentic records of a few of the earliest S.P.I. importations from Europe, so that nothing definite can be said as to their identity. Among these are No. 1492 (brown seeded), No. 1493 (black seeded), and No. 2156, Yellow Etampes, all from France. From these data it would appear that in 1909 at least ten varieties of soybeans were more or less grown in Europe.

The four varieties used by Haberlandt in his trials include with

scarcely a doubt Wisconsin Black, Ogemaw, and No. 17276, "Yellow." What the other yellow seeded sort may have been is doubtful. It could scarcely have been Etampes or Ito San, as that variety could hardly be expected to mature in Vienna.

Hawaiian Islands.—Soybeans are grown to some extent by the Japanese inhabitants. In Kona, Hawaii, the yield is said to be 600 to 1,000 lb. per acre from the early and medium varieties, and about double this quantity from the late sorts. It is estimated that about 200,000 lb. of seed are produced annually in the islands, but ten times this quantity is imported from Japan, especially for the manufacture of soy and miso. About 100 varieties have been tested by Krauss (1908, 1911) at the Hawaii Agricultural Experiment Station, many of them producing very satisfactorily.

Australia.—Numerous experimental trials with the soybean have been made, in Victoria, Queensland and New South Wales. The crop has not given promising results in New South Wales but success resulted in Victoria and Queensland for both seed and forage.

Africa.—Although the soybean was successfully cultivated as a rotation crop with corn in the upland, midland and coast districts of Natal and throughout the Gambia, Sierra Leone, Nigeria and Gold Coast Colony, it was not until about 1910 when everything pointed to a further advance in the price of all oil-seeds that special efforts were made to secure the adoption of the soybean as a South African staple. Previous to this time the prices for soybean seed offered little prospect of a remunerative crop except to the advantages as a rotation crop.

The first trials of soybeans at Cedara, Natal, in 1903 gave a maximum yield of 920 lb. to the acre. The third season's trial in the same field produced 1,252 lb. to the acre. It was found that imported seed for planting purposes gave very poor results whereas local grown seed resulted in satisfactory results. In West Africa the first experiments gave from 6 to 8 bu. to the acre, the low yields being due to the low viability of the seed. The continued poor germination of imported seed in various parts of Africa led to experiments which have resulted in the establishing of strains giving very satisfactory results. Results from the extensive experiments point to the fact that the soybean is adaptable to a wide range of elevation and temperature. In general, the climate most suitable for corn seemed

to furnish the required conditions for soybeans, although certain sorts gave most excellent results in the tropical conditions in the Gold Coast country. One of the greatest difficulties encountered in the culture of soybeans has been the finding of a satisfactory method of harvesting.

Extensive investigations have been made with all of the Governmental Experimental farms in Africa in cooperation with English firms handling oil and oil-seeds. It was found that beans grown in South Africa yield 20 to 22 per cent. oil, as against 15 to 16.5 for the same varieties grown in Manchuria.

Argentina.—Extensive experiments have been conducted with soybeans during recent years in Argentina, and the results have been such that many planters plan to grow the crop on a commercial scale in preference to linseed as a restorative crop in rotation with wheat. Tonnelier (1912) reports on the results of the work as to varieties, culture and analyses.

Canada.—Soybeans are grown in very small quantities in Canada and then usually as a forage crop. Experiments have been carried on by the Ontario Agricultural College for several years. About 20 varieties have been tried, but most require too long a season to mature. The very early maturing varieties and selections from these have been quite thoroughly tested in cooperative experiments as reported by Zavitz (1916). The Early Yellow (Ito San) variety has given an average of 15 bu. to the acre for the past 15 years. The average yields of twelve varieties grown in competition for the past 5 years at the Ontario Agricultural College are: O.A.C. No. 111-15.8 bu.; Buckshot, 15.8. bu.; Habaro, 15.7 bu.; Chernie, 15.5 bu.; Brown, 15.3 bu.; Quebec No. 92, 14.8 bu.; Early Yellow (Ito San), 14.2 bu.; Quebec No. 537, 13.6 bu.; O.A.C. No. 81, 13.4 bu.; Ito San, 13.3 bu.; and Medium Green (Guelph) 6.2 bu.

Philippines.—The soybean is not a native crop in the Philippines. Varieties imported from the United States, China and Japan, Java and India have been tried out at various times at the different experiment stations in Luzon. Variety trials at Singalong and Batangas gave returns of forage and seed that were unsatisfactory. At Alabang and Lamao, the plants grew normally in every way, but were one-third smaller than plants of the same variety in Virginia. Layosa (1918) and Norona (1919) have done considerable successful breeding work with

strains of this crop. At the present time the soybean is not recommended for general culture in the Philippines.

Egypt.—Tests with the soybean have shown that it succeeds as a summer crop. Seed was sown the latter part of June, and

FIG. 10.—Map of the Orient showing where the soybean is extensively and successfully grown.

the crop harvested at the end of September. When cut for hay nearly 6 tons to the acre were obtained. It was found that cattle, sheep and goats ate the fodder, but that donkeys and mules would not do so. The following yields of seed in pounds per acre were obtained: Manchurian, 1,257; Medium Yellow, 1,596; Elton, 1,061; Morse, 1,486.

Cuba.—Calvino (1920) conducted extensive tests with varieties from the United States relative to their adaptation, culture,

FIG. 11.—Map of North and South America, showing the regions where the soybean is being successfully grown.

yields and nutritive value. The yields in bushels per acre of varieties were as follows: Peking, 21.3; Early Brown, 17 1; Black Eyebrow, 16.4; Biloxi, 14.5; Hahto, 14.4; Virginia, 13.7.;

Wilson-Five, 13.6; Amarilla Nakasawa, 13.3; Arlington, 12.1; Mammoth, 8.1; Barchet, 7.6. The percentages of oil ranged from 15.6 (Arlington) to 19.2 (Biloxi) while the percentages of protein ranged from 28.1 (Virginia) to 39.1 (Hahto).

FIG. 12.—Map of Europe and Africa, showing where the soybean has been grown with success.

British Guiana.—Soybeans have been cultivated experimentally in several districts in British Guiana. The varieties under test, however, did not give very successful results.

Mauritius.—Trials with soybeans have not given very satisfactory results. If sown as early as May or June, the plants suffer from the effect of cyclones and torrential rains, whereas,

if sown later in the year, they are liable to attack by the "haricot fly" and to destruction by birds and small mammals.

Present Culture Distribution.—At the present time the soybean is cultivated abundantly in China, Korea, Manchuria, Japan (Fig. 10) and the United States (Fig. 11). It is still a crop of little importance in northern India, Indo-China and in the Malayan Islands. Soybean culture is also established in Italy, France, southern Russia (Podolia, Samarow), Hungary, Hawaii and South Africa (Fig. 12) but the extent of cultivation in each of these countries is small.

CHAPTER V

CULTURE OF THE SOYBEAN

The culture of the soybean presents no special difficulties. In the Orient the culture is mainly by hand but in the United States machinery is generally employed and is necessary to reduce the cost of production. Unsatisfactory results are most often due to lack of inoculation or else to the employment either of very early varieties which are of low yield or of sorts too late to mature.

The wild soybean is known to occur in southern Manchuria, Japan, and China. It is thus seen to be a plant of warm temperate regions. No information has been recorded as to the soil conditions which the wild plant prefers.

The mass of data that has been accumulated in the culture of the soybean emphasizes the fact that it is a plant adapted primarily to temperate regions with fairly humid warm summers. Even the Chinese have not been able to grow soybeans very successfully in the tropical portions of southern China. For some reason as yet obscure, under tropical or even subtropical conditions, the seeds fail to develop and the pods are empty. In the tropics the soybean may be expected to succeed only at considerable altitudes in the mountains or on islands where the influence of the sea may protect against too high temperature.

In regions with a decidedly cool summer climate, the soybean is not well adapted. In most of Europe only the very early varieties will mature, and such varieties are dwarf and of low yield.

Climatic Adaptations.—The conditions under which the soybean thrives are said to be far more varied in Manchuria than in any other country. The crop succeeds equally well in semi-arid regions, in valleys subject to floods for several weeks during the rainy season, and in northern latitudes having a growing season similar to that of the Dakotas and Minnesota. The soybean may be seen from the shores of the Yellow Sea to as far north as 52 degrees of north latitude, but the region most suitable is the

upland country beyond Mukden in about 44 degrees north latitude (Fig. 13).

In general, the climatic adaptations of the soybean in America

FIG. 13.—Map of Manchuria, showing the soybean districts and seed production of different localities.

are about the same as for varieties of corn and cotton (Fig. 14). It is especially adapted to the Cotton Belt and northward into the southern part of the Corn Belt where the larger and later varieties, which give yields that make their extensive cultivation

profitable, can be grown. However, in the northern states, early varieties obtained from northern Manchuria mature fair yields of seed while later varieties are grown successfully for forage and ensilage purposes. Under conditions in the southernmost parts of the Gulf States most soybean varieties seldom grow normally. Although a satisfactory growth of forage is obtained, the pods fail to fill well. Similar conditions exist in Arizona, New Mexico, and parts of California where extremely hot weather prevails during the period when the pods are forming. The soybean is less susceptible to frost than either the cowpea or corn, light frost having but little effect on the plants when

Fig. 14.—Outline map of the United States, showing the areas to which the soybean is especially adapted as to varieties and purposes: (1) the later and larger varieties for seed production; (2) medium and medium-late varieties for seed and the same varieties and later varieties for forage; (3) very early varieties for grain production and the medium and medium-late varieties for dry forage and for ensilage.

young or even when nearly mature. If the seeds are fairly well developed before a killing frost occurs they will usually ripen satisfactorily. The soybean is more drought resistant, and also less sensitive to an excess of moisture than either corn or cowpeas. It seems to thrive remarkably well in a season of drought, and in a wet season neither growth nor production is seriously reduced.

Soil Preferences.—The soybean has been found to succeed on nearly all types of soil. The best results, however, as experiments have shown, are obtained in sandy or clay loams containing fair quantities of potash, lime and phosphoric acid. In general, the soil requirements of the soybean in the United States may be said to be about the same as for corn, provided inoculation is present, but the crop will not make nearly as good growth in poor

soils as cowpeas. Although the soybean does not require a well-drained soil for good results, it will not succeed in a soil where water stands for any considerable length of time. Swamp and peat soils after being drained and limed have usually been found to produce this crop very well. On the muck and semi-muck soils in eastern North Carolina excellent yields of beans and forage are produced and the crop occupies an important place in the farming systems of that region. With inoculation and moderate amounts of fertilizers the soybean grows well in the sandy soils of the Coastal Plain area.

Fig. 15.—Soybeans grown on the edges of a rice field in southern China. (*Photographed by F. N. Meyer, Agricultural Explorer, U. S. Dept. of Agr.*)

In Manchuria the soybean is to be seen growing everywhere, and flourishing even in quite sandy soils. The best results are obtained, however, in the upland country beyond Mukden where the hills—the product of the decomposition of palaeozoic rock (gneiss)—are overlaid with wind-deposited soil which, being friable, is peculiarly suitable for the growth of a shallow-rooted plant like the soybean. The bean grows well in the river bottoms with their water-deposited soils from the river beds of the Liao and Sungari Rivers and their affluents. In these districts the rich loamy soil guarantees bountiful harvest in all but abnormal years. The soil in south Manchuria is said to be less suitable for

the best results with the soybean than that of north Manchuria.

The soybean succeeds best in soils of a medium texture in Japan. It also succeeds in comparatively light soils, often giving an abundant crop on soils too poor to grow clover. Good results have been obtained in Europe on a great variety of soils. In South Africa good crops were raised on old farm land, newly-broken farms and on irrigated lands. Variety tests by the government experiment station show that the soybean succeeds there on a great variety of soils.

Water Requirement.—In tests at Akron, Colo., in an inclosure which reduced solar radiation to 80 per cent. of normal, Briggs and Shantz (1914) found that soybeans required 744 lb. of water to produce 1 lb. of dry matter. Results obtained by Whitson (1902) at the Wisconsin Station show that soybean plants used 527 lb. of water to produce 1 lb. of dry matter. A yield of 7,980 lb. of dry matter to the acre, equal to 9,177 lb. of hay with 15 per cent. moisture, was produced and the quantity of water used was 18.68 in.

Preparation of Seed Bed.—In China, Japan and Manchuria soybeans are almost entirely produced by hand methods. The fields are rarely broken up and prepared before planting, the cultivation, therefore, taking place after the bean plants begin to grow. Both in China and Japan the soybean is frequently planted along the edges of rice or wheat fields and on the new-built dykes of rice fields (Fig. 15). These edges are, as a rule, very soft, for they have been previously prepared so that little labor is required in planting. When a field is to be planted exclusively to soybeans, it is fitted well. In the mountain districts of Japan where the farms are terraced land is often chosen which has laid fallow all winter, or wheat or barley fields are used. The soybean seeds are put into holes beside the stalks of ripening winter grains.

In the United States the fitting of the soil is similar to that for corn. Soybeans like corn, readily respond to any extra soil preparation. When the soybean is to occupy the land the entire season, it should be plowed early and deep, fitted and then harrowed at intervals until the beans are planted; otherwise, weeds are likely to choke out the young plants. Thorough disking will give the proper preparation after a crop of early potatoes or peas, or on stubble land after wheat or winter oats, provided the soil is moist and mellow. A seed bed with a light, loose covering

of mellow soil, well smoothed by the harrow, is conducive to uniform depth in planting and to a good stand of plants. A soil free of clods insures the best results, especially in seeding broadcast, which may be desirable in the better soils.

Time of Planting.—Soybeans may be sown at any time after danger of severe frosts is over. The plants, however, grow slowly in cool weather and ordinarily there is no advantage in planting earlier than corn. In general, the best time for seeding may be said to be about that for corn.

In a series of time of planting tests, Mooers (1908) at the Tennessee Experiment Station found the extreme dates of successful planting to be April 3 and August 6. At the later date the Ito San variety produced 13 bu. of seed per acre. June proved to be the most favorable month in which to plant any variety.

Results secured in a series of dates of planting tests with the Haberlandt variety at Arlington Farm, Va., are shown in the following table:

Table XVIII.—Acre Yields of Seed and Hay of Soybeans at Different Dates of Planting at Arlington Farm, Virginia

Date of planting	Green forage		Hay		Grain	
	1915, tons	1916, tons	1915, tons	1916, tons	1915, bu.	1916, bu.
May 1	8.92	8.70	2.09	1.96	33.3	27.6
May 15	10.06	8.36	2.39	2.09	34.0	25.3
June 1	8.55	4.22[1]	1.90	1.03[1]	33.3	10.3[1]
June 15	7.54	7.84	1.83	2.00	25.3	21.3
July 1	7.18	7.97	2.00	1.82	24.3	23.6
July 15	6.18	4.27	1.50	1.12	19.3	12.0
August 1	2.63	3.64	0.87	0.94		

The time of planting in Japan is between May 20 and June 10 in the northern and eastern provinces, and as early as April in the southern and western sections. In some parts of China and Manchuria the seed is sown as late as June while in other parts in April.

Methods of Seeding.—Under nearly all conditions the soybean should be grown in rows (Fig. 16) and given sufficient cultivation to keep down the weeds. The yield of seed is nearly always

[1] Poor stand due to pigeons eating the seedlings.

Fig. 16.—A field of the Peking variety of soybean grown in rows and cultivated.

Fig. 17.—A broadcast field of soybeans showing how weeds have overrun the field.

greater when grown in cultivated rows. However, if the land is quite free from weeds and the crop is to be used for hay, soiling, or green manure, drilling broadcast will furnish a forage of finer quality. The main objections to solid drilling are the larger amounts of seed required and the greater growth of weeds in cold wet seasons (Fig. 17). Broadcasting and covering the seed with a harrow is seldom advisable.

Spacing.—The width between rows varies from 24 to 36 in., most often 36 in. so as to facilitate easy cultivation. The plants of different varieties range in height from 1 to 5 ft. or more, so the optimum distance apart of rows is thus partly a matter of variety and partly one of the culture implements to be employed. In eastern North Carolina, the soybean is planted in rows 4 ft. apart and ridged to facilitate drainage. The plants should generally occur about every 3 or 4 in. in the row. Few tests as to different plant spacings have been reported, but the results shown in the following table give some indication as to the relative merits of different distances.

Table XIX.—Yields of Soybeans Variously Spaced

Distance between rows	Yield of grain			Yield of forage	
	Illinois, bu.	Indiana, bu.	Tennessee, bu.	Indiana, tons	Tennessee tons[1]
Broadcast	18.30	13.10	.....	2.95	
Drilled solid	17.00	21.23	12.20	3.04	2.94
14 in.	19.04				
18 in.	.....	.....	24.50	.....	2.74
21 in.	22.42				
24 in.	.....	.....	16.3		
28 in.	19.66	20.8	.....	2.85	
30 in.	.....	.....	18.5		
35 in.	21.10	19.5	.....	2.41	
36 in.	.....	.....	15.4		
42 in.	19.9	19.4	.....	2.04	

Grantham (1912) in a five-year test at the Delaware Station comparing methods of sowing obtained 5.9 bu. difference per acre in favor of drilling solid. Where the soybeans were cultivated, only two-ninths as much seed was used as where sown solid. In these experiments the drilled rows were 32 in. apart and cultivated three times.

[1] Straw.

The ordinary grain drill furnishes, perhaps, the most convenient means for seeding in rows or broadcast. The width of rows may be adjusted by covering the feed cups not in use (Fig. 18). To prevent splitting of the seed, the oats feed should be used. Corn planters can be satisfactorily used, as most of the modern planters have special plates for planting beans. In the southern states the cotton planter is used quite extensively.

In China and Manchuria, the beans are planted in some districts in rows about 17 in. wide, the plants about 2 in. apart in the rows. In other districts, the beans are planted in

Fig. 18.—The ordinary grain drill furnishes a most convenient method of seeding in rows or broadcast.

24 in. rows, allowing about 7 plants to the foot. These widths of rows allow the small horses or donkeys to draw a crude, one-horse plow of the single shovel type between them. This naturally throws the soil into ridges so that by the time the beans are laid-by the plants are growing on top of ridges 5 or 6 in. high. In Japan, furrows are made about 2 ft. apart and the seeds are sown, two or three together, about 10 in. apart. This method of planting is also practiced quite extensively in central and northern Manchuria.

Rate of Seeding.—The quantity of seed to be sown to the acre will vary somewhat according to the size of the seed and the

purpose for which the crop is grown. Rate of seeding experiments indicate that with rows from 24 to 36 in. apart from 20 to 30 lb. is satisfactory and when sown broadcast for hay, from 1 to 1½ bu. of seed is required. Results secured at different experiment stations with rate of seeding tests are shown in the following table:

TABLE XX.—ACRE YIELDS OF SOYBEAN HAY AND SEED WHEN PLANTED AT DIFFERENT RATES

Rate of seeding to the acre, lb.	Width of rows, in.			Thrashed grain			Hay		
				Ohio, bu.	Indiana, bu.	Tennessee, bu.	Ohio, tons	Indiana, tons	Tennessee, tons
15	28	..	..	20.26	....	....	1.62		
30	28	24, 28	36	20.31	20.8	15.4	1.62	2.85	2.39[1]
36	..	..	30	.....	....	18.5	....	....	3.13[1]
40	..	8	..	.....	21.1	....	....	3.05	
45	28	..	24	22.49	....	16.3	1.77	....	2.77[1]
60	28	..	18	22.05	21.7	24.5	1.70	3.18	2.74[1]
90	..	..	..	.....	20.9	.....	....	2.95	
120	8	..	8	19.68	....	12.2	2.07	....	2.94[1]

From 20 to 30 lb. of seed to the acre are sown in the interior of Manchuria while on the coast and in the river valley regions about one-half of this amount is used. In Japan where the manner of seeding is somewhat different, the rate of seeding is estimated at about ⅗ bu. to the acre.

Seeding Soybeans for Pasturage.—Different methods of seeding soybeans to be pastured are used in various sections of the country. In the southern states, especially North Carolina, where a considerable acreage is used for hog pasture, from 1½ to 2 bu. of beans are sown broadcast in rows at the last working of the corn. The hogs are then turned in when the seed is fully mature. The two crops are sometimes grown together and then pastured down, as is often done with corn. The corn and soybeans may be planted in alternate rows (Fig. 19) or mixed and drilled in the same row. In many instances, especially for young hogs, the beans are planted alone in fields. The grazing period may be prolonged

[1] Straw.

for hogs by planting early, medium, and late varieties. By this method of planting, pasture would be supplied for a period of several weeks. Early maturing varieties may be sown after wheat and oats and make sufficient growth for considerable feed in the fall.

FIG. 19.—Soybeans and corn grown in alternate rows for pasturage.

Depth of Seeding.—The depth of planting soybean seed is quite important, poor stands frequently resulting from too deep planting. The depth should not exceed 2 in. in the heavier types of soil, since with shallow planting chance of failure due to formation of a soil crust is lessened. In sandy soils a deeper planting, 2 to 4 in., can be made with good results. In a test under favorable conditions with the Mammoth Yellow and Peking varieties, 100 seeds each were planted respectively 1, 1½, 2, 2½, 3 and 4 in. deep. The percentages of plants reaching the surface one week after planting are shown in the following table:

TABLE XXI.—GERMINATION OF SOYBEANS AT DIFFERENT DEPTHS OF PLANTING AT ARLINGTON FARM, VIRGINIA

Variety	Per cent. germination at different depths					
	1 in.	1½ in.	2 in.	2½ in.	3 in.	4 in.
Mammoth....	100	93	98	95	92	84
Peking.......	95	97	92	92	90	86

At the Tennessee Experiment Station Mooers (1912) found that the Ito San variety failed to reach the surface when the seed was planted 6 in. deep. At 5 in. the stand was very poor

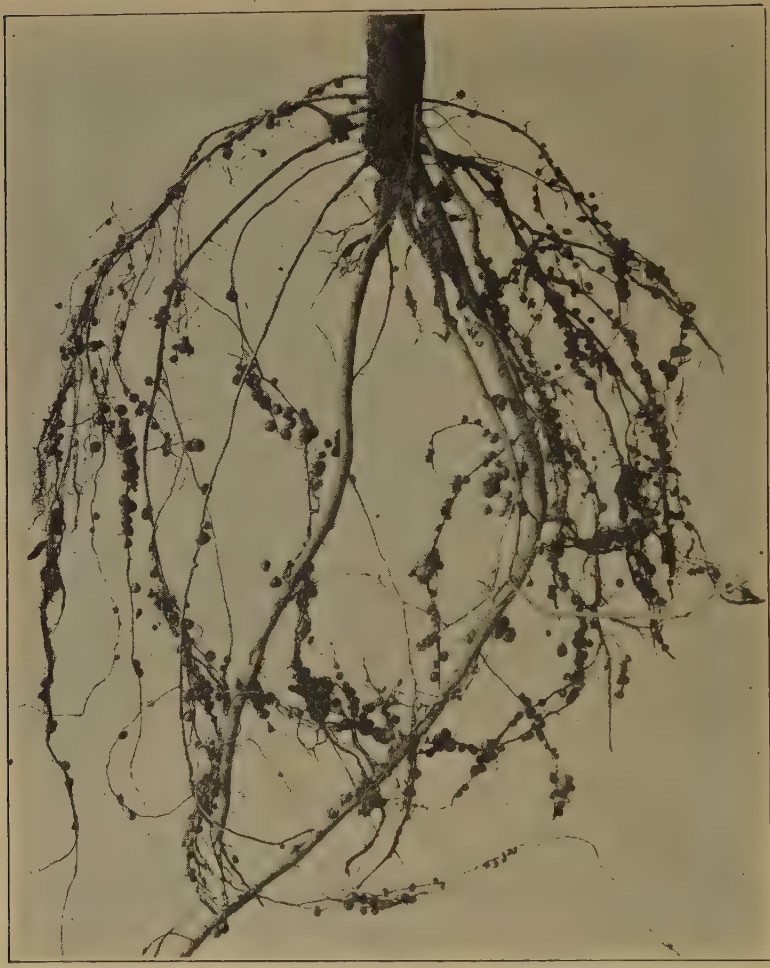

FIG. 20.—Roots of a soybean plant, showing abundant development of nodules.

but it was apparently perfect at any depth of planting between 1 and 4 in.

Inoculation.—In common with most other legumes, soybeans are able to utilize the nitrogen of the air through the action of bacteria which live on the roots of the plant. The presence

of these organisms, a peculiar strain of which occurs on the soybean is indicated by the development of nodules or tubercles on the roots (Fig. 20). Soybeans are inoculated with the bacteria from the soybean nodule only. Klimmer and Kruger (1914) made a detailed study of nodule bacteria from eighteen different legumes, belonging to nine sharply defined groups. The soybean fell in a group by itself. On soils poor in nitrogen, soybeans will make an indifferent growth unless the bacteria are present (Fig. 21). A pale or greenish-yellow color of the plant

FIG. 21.—A plat of soybeans without inoculation (in the foreground) and an adjacent plat which had been inoculated (in the background).

is very often an indication of lack of nodulation. Soybeans, however, give very good results in rich land, even though the bacteria are not in the soil, but in such cases the nitrogen will be taken from the soil, and, therefore, it will not be increased as is the case when the bacteria are present.

Artificial Inoculation.—Natural inoculation now occurs quite generally throughout much of the regions where soybeans are grown extensively. However, when the crop is planted in land that has not previously grown the crop it is advisable to inoculate. Without doubt most of the unsatisfactory results in the first trials with soybeans are due to lack of proper bacteria. Inoculation may be obtained either through the use of pure culture, which may be purchased, or by the use of inoculated soil from a field where the plants have previously developed nodules.

While artificial cultures may prove satisfactory, it is believed that the soil method will prove cheaper and more efficient in most cases. It is essential that the inoculating material be placed under the surface, and using the grain drill with the fertilizer attachment will prove the best method. Another soil method, equally efficient, is the thorough mixing with a bushel of beans about 1 gal. of finely sifted inoculated soil. After soybeans have been grown on one field on the farm, soil can be taken from this field and used to inoculate other fields.

In an inoculation test of commercial cultures, Fellers (1918*b*) found that soybeans were harder to inoculate than most of the common legumes, many of the cultures failing to give satisfactory results with this plant.

Variations in Nodule Formation.—Variations in soybean inoculation with different varieties have been observed. Voorhees (1915) in a study of several varieties found the plants of all varieties bore root nodules except the Haberlandt, which seemed to lack them entirely. The Mikado had numerous nodules, spreading around the top root in a close mass, this also being true to a less extent with the Auburn and Mammoth Brown varieties. The Tarheel Black had a few large nodules scattered on the finer roots as far as 8 to 12 in. from the tap root. In two rows, where the Haberlandt and Mammoth Brown varieties were mixed in planting, the root systems became rather closely associated. After separating the roots of the two varieties, it was found that the Mammoth Brown variety had numerous nodules scattered throughout, but no nodules were found on the roots of the Haberlandt. Voorhees is of the opinion that different varieties of the same legume bear different and definite powers of resistance to association with symbiotic bacteria. Somewhat similar results in soybean inoculation were noted by the junior author at the West Tennessee Experiment Station, Jackson, Tenn., in 1911. The Acme and Tokio varieties lacked root nodules, while the Mammoth variety planted under the same conditions, produced many of them.

Difference in susceptibility to inoculation between varieties of soybeans and in some cases even total resistance to inoculation, as had been reported by several investigators, has been shown by Leonard (1916) not to exist in the 19 varieties of soybeans tested by him under laboratory and greenhouse conditions. The smoothness and oily nature of soybeans has been suggested

by Fellers (1918*b*) as possibly presenting some of the difficulties in soybean inoculation.

Relation of Nodulation to Yield and Composition of the Seeds.—In experiments to study the influence of nodules, it was found by Smith and Robinson (1905) of the Michigan Experiment Station that, although the presence of the bacteria on the roots in a fairly rich soil may not notably increase the yield, the inoculated plants were far richer in protein and therefore of greater value than the ones not inoculated. In Table XXII are given the results of the above experiments, showing the influence of the nodules on the composition of the ripened seed.

Table XXII.—Influence of Nodules on the Composition of Seed. Michigan Experiment Station

	Moisture, per cent.	Protein, per cent.	True proteids, per cent.	Fat, per cent.	Fiber, per cent.	Carbo-hydrates, per cent.	Ash, per cent.
Ogemaw:							
Not inoculated......	8.08	35.39	22.69	15.66	5.18	30.52	5.17
Inoculated..........	8.88	42.20	31.28	13.36	5.20	26.13	4.23
Medium Green:							
Not inoculated......	8.12	31.23	21.46	17.38	5.92	32.22	5.13
Inoculated..........	8.80	36.45	24.51	16.27	5.40	27.96	5.12

In a study of the value of nodule formation at the Cedara, South Africa, Experiment Station, the leaves and stems of the plants provided with nodules contained 2.78 per cent. of nitrogen and those without nodules only 1.77 per cent. in the dry matter. The nodules themselves contained 4.19 per cent. nitrogen. The presence of nodules did not seem notably to affect the content of phosphoric acid or potash in the plant. Basing calculations on the composition of dry matter in the leaves, stems and roots, it is estimated that the soybean crop with nodules contained 113.5 lb. of nitrogen to the acre, as compared with 75.98 lb. from that without nodules.

Although previously stated that inoculation may not notably increase the yield, the inoculated beans may show an increased growth over the uninoculated ones. In 1915, Prince (1917) in a test at the New Hampshire Experiment Station found the inoculated plot of soybeans gave 7.192 tons in green weight to the acre, while the uninoculated plot gave 4.672 tons, thus representing the gain for inoculation 2.520 tons to the acre.

Fellers (1918*a*) found in New Jersey that inoculation gave

a substantial increase in the yield of total dry matter and of soybeans in every case. In inoculation tests by Eastman (1922) at the New Hampshire Station, the inoculated plants showed a remarkable difference in color and also in the number of root nodules in comparison with the uninoculated. Chemical analyses showed 2.26 per cent. nitrogen in the leaves and stems of the inoculated plants as against 1.79 per cent. in the uninoculated—that is the inoculated plants contained about 26 per cent. more nitrogen than the uninoculated.

At the Wisconsin Experiment Station, Woll and Olson (1907) grew the Wisconsin Black variety of soybeans both on inoculated and on uninoculated soil. Analyses of the crops indicated that inoculation of the soil increased the nitrogen content of the plant, the percentage of fertilizer ingredients in the roots, and the protein content of the beans; and decreased the percentage of ash constituents in the plant. It will be noted that these results coincide with those obtained in a similar experiment at the Michigan Station. Fellers (1918) found in New Jersey that with inoculation the protein content increased, in direct proportion to the completeness of infection.

Relation of Nodule Formation to Fertilizers.—Fellers (1918*a*) at the New Jersey Experiment Station found that on sour soils, liming stimulated nodule production to a marked degree—in some cases as much as 1,500 per cent. Nodule production was also stimulated on limed soils by acid phosphate, but this was not so marked on acid soils. With potash (muriate) in applications of from 50 to 400 lb. per acre, nodule production was slightly stimulated on the limed plots, but not on the unlimed. Nitrate of soda inhibited nodule formation and consequent fixation of atmospheric nitrogen. Manganese sulfate did not stimulate nodule production. Land plaster (600 lb.) was found to increase the production of nodules.

Investigations at the Cornell Experiment Station by Wilson (1915) in physiological studies of *Bacillus radicicola* confirm earlier work regarding the influence of nitrates on nodule production and indicate that sulfates in relatively weak concentration inhibit the process. Chlorids and phosphates stimulate nodule production, while ammonium salts are inhibitory. It was determined that while nodule development was prevented by the presence of nitrates, sulfates and ammonium salts, yet the organism retained its vitality in the presence of these salts.

Acidity, according to Bryan and Fred, (1920) of the Wisconsin Experiment Station influences the inoculation of soybeans. Investigations showed that cowpeas and soybeans dropped off markedly in both growth and nodule formation as soon as an excess of either acid or alkali appeared in the soil. Corn, on the other hand, made a reasonably satisfactory growth even under acid conditions which were sufficient to prevent the inoculation and to stunt both soybeans and cowpeas.

Effect of Soybean Germination on Bacteria.—Haas and Fred (1919) at the Wisconsin Experiment Station conducted a series of investigations as to whether or not the germination of legume seed has by its excretions an injurious effect upon the growth of the nodule-forming bacteria with which the seed have been inoculated. It was shown in the studies upon yellow soybeans that the germination of the seed favors the growth of bacteria. When bacteria-free soybean seeds were obtained directly from the pods and inoculated with soybean bacteria, no toxic action of substances excreted from the germinating seed upon the growth of the nodule bacteria was observed.

Vitality of Soybean Bacteria in the Soil.—No experimental data seem to exist as to the length of time legume bacteria live in the soil. Fred and Davenport (1922) at the Wisconsin Experiment Station state that in a rich silt loam neutral soil, soybean bacteria have been known to live more than 18 years, but as a rule the number of legume bacteria in a soil free from legumes decreases rapidly after 2 or 3 years, and in an acid soil the disappearance is even more rapid.

Fertilizer Reactions.—When grown on land giving good yields of corn or following corn grown on a well-manured sod, an excellent crop of soybeans may be expected without direct applications of fertilizers. The use of fertilizers, however, is recommended where the soil is sandy or relatively poor. Numerous tests have been conducted by various American experiment stations as to the fertilizer requirements of the soybean.

In China and Manchuria the only fertilizer applied is a compost of stable manure and earth, the latter often taken from pools formed in the roads. The kinds of fertilizers used in Japan differ by districts. In some provinces straw ashes and superphosphate of lime are commonly employed, while in others wood ashes, superphosphate of lime, and manure are used.

Nitrogen.—Special experiments were carried on at the Con-

necticut Storrs Station, by Phelps (1895, 1900, 1901) and by Atwater and Phelps (1898, 1899), to study the effects upon the yields when different kinds and quantities of nitrogenous fertilizers were used in addition to uniform quantities of mineral fertilizers, and to study the effect of the nitrogen in the fertilizers upon the percentage and amount of protein in the crop. The results secured indicate that while mineral fertilizers are of great value in increasing production, nitrogenous fertilizers do not greatly increase the yield or percentage of protein in the crop over that obtained from the mineral fertilizers only. The percentage and yields of protein in the soybean bear very little relation to the quantities of nitrogen used.

Flagg, *et al.* (1894) at the Rhode Island Station found that with eighteen legumes the application of 150 lb. of nitrate of soda to the acre seemed more profitable than 450 lb. The clovers seemed most benefited by the smaller application, while with soybeans this application did not pay the cost the second year.

In a series of tests by Brooks (1904) at the Massachusetts Experiment Station manure and other fertilizers furnishing nitrogen were compared. Table XXIII gives the yields of beans and straw obtained with various nitrogen fertilizers.

Table XXIII.—Effect of Various Nitrogenous Fertilizers on the Yield of Soybeans. Massachusetts Experiment Station

Nitrogen fertilizer	Beans, bu.	Straw, lb.
Manure (most of potash used contained in manure)	23.8	2,010
Nitrate of soda (muriate of potash)	20.5	1,700
Nitrate of soda (sulfate of potash)	24.8	2,080
Dried blood (muriate of potash)	16.7	2,015
No nitrogen (sulfate of potash)	17.1	1,705
Sulfate of ammonium (sulfate of potash)	16.9	1,480
Sulfate of ammonium (muriate of potash)	11.6	1,160
No nitrogen (muriate of potash)	11.1	1,125
Sulfate of ammonium (muriate of potash)	14.8	1,390
No nitrogen (muriate of potash)	8.8	745
Dried blood (sulfate of potash)	21.7	1,225

Phosphorus.—At the Rhode Island Station, Hartwell (1920) found the ability of soybeans to secure their needs for phosphorous to rank between that of carrots, which obtain their full require-

ments, and turnips which were practically unable to grow without phosphatic application.

In a series of experiments by the Rhode Island Experiment Station the effects of nine different phosphates upon limed and unlimed land with Medium Green soybeans are shown in the following table:

Table XXIV.—Effects of Different Phosphatic Fertilizers with and without Lime. Rhode Island Experiment Station

Kinds of phosphates	Green forage		Grain	
	Limed, lb.	Unlimed, lb.	Limed, bu.	Unlimed, bu.
Dissolved bone-black	170	122	27.5	23.3
Dissolved bone	160	126	29.3	26.8
Acid phosphate	160	126	27.7	25.3
Fine ground bone	161	129	29.3	27.5
Basic slag meal	178	152	29.8	27.3
Floats	141	143	26.5	23.6
Redondite (raw)	99	110	17.2	16.0
Redondite (roasted)	140	109	24.6	19.1
No phosphate	102	75	16.7	14.2
Double superphosphate	113	102	25.3	19.7

Potash.—Experiments to determine the relative value of muriate and high grade sulfate of potash by the Massachusetts Experiment Station extended over a period of fifteen years. It was found that the average of all trials was favorable to the sulfate, and it would seem that there can be little doubt that where the two potash salts are continuously used the

Table XXV.—The Influence of Different Potash Salts on Yields of Soybeans. Massachusetts Experiment Station

Potash salt	Beans, bu.	Straw, lb.
No potash	22.72	1,896
Kainit	16.96	1,350
High-grade sulfate	25.86	1,984
Low-grade sulfate	22.76	1,712
Muriate	23.03	1,728
Nitrate	23.38	2,036
Carbonate	27.86	2,288
Silicate	25.40	2,024

sulfate rather than the muriate should be selected. The superiority in yield with the former is usually much more than sufficient to cover the small additional cost of that salt as compared with the muriate. The results obtained in the application of different potash salts are shown in Table XXV.

The Rhode Island Experiment Station found that soybeans were able to derive two-thirds of their potassium needs from a soil so poor in potash that mangels could obtain only one-fourth and summer squash about one-tenth of their requirements.

Lime.—The results shown in Table XXIV and similar experiments with other plants indicate that the soybean can thrive quite well upon soil so "acid" and so poor in carbonate of lime that many other crops can not be grown successfully. However, it will be noted that lime invariably increases the yield of the soybean, and in the unlimed series the floats gave a better yield than any other phosphate, with the single exception of basic slag meal.

The Massachusetts Experiment Station began in 1914 an experiment to study the relative value of different sources of lime on the basis of equal applications of combined calcium and magnesium oxides. The following table gives results obtained up to 1914.

Table XXVI.—Effects of Different Kinds of Lime on the Yield of Soybeans. Massachusetts Experiment Station

Fertilizer	Before liming, 1913		After liming, 1914		Beans, bu.	Straw, lb.
	Hay to acre, lb.	No lime equals 100 to acre, per cent.	Soybeans, weighed green, lb.	No lime equals 100 per cent.		
Tobey lime....	5,284	141.7	13,692	148.0	31.20	2,484
Marl..........	5,010	134.0	13,738	148.5	30.00	2,435
Ground limestone........	4,490	120.0	9,887	106.9	30.02	2,359
No lime........	3,730	100.0	9,250	100.0	28.86	2,273
Limoid........	5,100	136.7	10,437	112.8	35.25	3,209

At the New Jersey Station, Lipman *et al.* (1914) found that liming was followed by an average increase of 150 lb. of beans in the yield of seed for the varieties grown on limed and unlimed land. In 1913 at this station the limed plats gave an average increase of total dry matter to the acre of 1,105 lb., and an

average increase of seed of 203 lb. as compared with unlimed plats. Moreover, different fertilizing materials did not greatly influence the percentage of nitrogen in the dry matter, but judicious liming increased the nitrogen content of both vines and seed.

Lipman and Blair (1918) in a study of the influence of lime on the number of nodules and the percentage of nitrogen when soybeans are harvested for hay found in New Jersey that the average yield of dry matter from 12 plants from the limed plats was 84.4 gm. and from the unlimed plats 46.5 gm. The percentage of nitrogen in the dry matter was 0.25 per cent. higher for the limed than for the unlimed plots. On the limed plats an average of 85 nodules, and on the unlimed plats of 37 nodules per plant, was found. Of six varieties grown to maturity on both series of plats all gave the higher yield of beans and straw on the limed plats, the average increase being 5.5 bu. of beans and 800 lb. of straw. Plants harvested for forage showed an average nitrogen content in the tops of 3.08 per cent. on limed plats and 2.67 per cent. on unlimed plats, and in the roots 1.47 per cent. and 1.24 per cent. respectively.

Ground oyster shells and burnt lime were both found by Fellers (1918) to be very efficient in increasing the yield and total dry matter of soybeans on acid soils in New Jersey; the increases varying from 30 to 50 per cent. Small applications (1,000 to 2,000 lb. per acre) were nearly as beneficial as larger amounts, and are deemed preferable, if made at intervals of a few years, to a single large application. Liming seemed to stimulate nodule production by as much as 1,500 per cent. in some cases, appearing to be nearly as important as inoculation, although it is stated that both should be practiced for the best results. Nodule development did not take place readily on acid soil, even when the root-infecting organisms were plentiful in the soil. Small amounts of lime were nearly as effective in raising the protein content as larger applications.

Sulfur.—Shedd (1914) in Kentucky obtained decided gains in the growth of soybeans with applications of sulfur, ammonium sulfate, pyrite, and ferrous sulfate, and smaller gains with calcium, potassium, barium, magnesium, aluminum, and sodium sulfates on a soil containing 600 lb. of sulfur and 3,400 lb. of phosphorus to the acre. The best results were obtained with elemental sulfur. Pyrite and ferrous sulfate were applied at rates furnish-

ing 6 lb. of sulfur to the acre. The sulfur content of soybeans which had responded to sulfur fertilization was in all cases higher than that of beans which had not been fertilized with sulfur. Fellers (1918) in New Jersey found that sulfur did not show increased yields of dry matter or seed in applications of over 100 lb. to the acre, and that large amounts seemed to injure the plants. The protein content appeared to be increased by moderate applications of sulfur, but was decreased by large applications, the exact reverse being true in the case of the oil content. Calcium sulfate in amounts up to 600 lb. per acre seemed to exert little influence on the yield of total dry matter or seed. The results obtained with zinc sulfate and ferric sulfate were deemed inconclusive, but these minerals seemed to stimulate plant growth and to give increased seed production. The protein content was also apparently somewhat increased.

Lipman *et al.* (1921) in a series of experiments in New Jersey using inoculated and uninoculated sulfur at the rate of 200, 500, 1,000, 2,000 and 4,000 lb. to the acre found with 200 lb. of sulfur the germination and growth of soybeans to be about normal. With 1,000 lb. and over, germination was very materially depressed, there being very few plants on the plots that received 2,000 and 4,000 lb. of sulfur.

Phosphorus and Potash.—In availability work with phosphorus and potassium compounds, Lipman *et al.* (1917) found in New Jersey that when soybeans were grown in coarse, white sand, basic slag as a source of phosphorus gave about as good yields as acid phosphate. Under the same conditions, blue rock phosphate yielded only slightly more than the check. Brown rock gave somewhat better yields than the blue rock. An average percentage of nitrogen in the dry matter of soybean hay was about the same with basic slag as with acid phosphate. It was distinctly and uniformly less with raw rock and also where no phosphate was used. On the white and also on the yellow sand, soybeans, when inoculated and supplied with available phosphates and lime, gave practically as good yields on the check pots as on the marl-treated pots up to the time the pods were about one-half filled. When allowed to mature there was an appreciable falling off in the yield of seed on the check pots, but the yield of stalks was about the same on the check pots as on the treated pots. Dry matter of soybean

hay from check pots and from marl-treated pots contained quite as high percentage of nitrogen as that from pots treated with a soluble potash salt. The percentage of potash (K_2O) in the dry matter of soybean hay from pots treated with soluble potash was notably higher than in that from marl-treated pots on the check pots, but this appears to be a "luxury" consumption since the yield of dry matter and the percentage of nitrogen are not thereby increased. The work indicates that there is a very close connection between the presence in the soil of soluble phosphates and the accumulation of nitrogen by the soybean plant.

At the Delaware Station commercial fertilizers do not seem to show marked results when applied to soybeans planted on good corn land. Fertilizer experiments at this station show only a small increase on yield of soybeans from the use of commercial fertilizers. In the following table it will be noted that there is little difference between the fertilized plants and those not treated for an average of years.

Table XXVII.—Effect of Fertilizers on Soybeans. Delaware Experiment Station

Plat No.	Fertilizer	Rate, lb.	Bushels per acre				
			1908	1909	1910	1911	Average
1	Acid phosphate	300	26.5	21.8	23.0	29.0	25.1
2	Muriate of potash	100	26.5	20.6	22.3	29.5	24.7
3	Nothing	...	27.0	22.1	20.2	27.5	24.2
	Acid phosphate	300					
4	Muriate of phosphate ..	100	24.3	22.8	18.0	27.5	23.2
	Acid phosphate	450	25.6	24.8	21.3	27.5	24.8
5	Muriate of potash	150					

As a general formula for soybeans, Mooers (1908) of the Tennessee Experiment Station recommends: acid phosphate, 300 lb.; wood ashes, 250 lb. or muriate of potash, 50 lb. Where neither wood ashes nor the muriate is to be had, acid phosphate alone may be used to great advantage, 200 to 300 lb. to the acre being considered a fair application. Wood ashes in the quantity recommended are said to be superior to the potash (muriate) for they contain on the average 30 to 40 per

cent. of lime and some phosphoric acid in addition to about 5 per cent. of water-soluble potash.

Radium.—Field experiments at the Illinois Experiment Station with soybeans and corn in which radium fertilizer was used at rates furnishing 0.01, 0.1 and 1 mg. per acre are reported by Hopkins and Sachs (1915). The soybeans followed the corn on the same land without additional application of the radium fertilizer. In all cases the average variation from the check was so slight and so evenly distributed for and against as to lead only to the conclusion that radium applied at a cost of $1.00, $10.00 or $100.00 per acre produced no effect upon the crop yields either the first or second season.

Relation of Maturity to Fertilizers.—Shuster (1922) at the Delaware Experiment Station carried on a series of experiments relative to the influence of fertilizers on yield and maturity of soybeans. The presence of muriate of potash in fertilizers was found to bring the beans to earlier maturity, which is in accord with the results of Lipman and Blair (1917) at the New Jersey Experiment Station. Applications of 3 to 5 tons of manure to the acre favor early maturity probably due to the potash contained and gave the largest yields. In the absence of manure, acid phosphate, 250 lb., and muriate of potash, 75 lb., are recommended to the acre. With lower priced potash, more potash should be used. Nitrate of soda did not produce desirable results with soybeans, as to maturity, yield or financial returns.

Cultivation.—The soybean readily responds to good cultivation and often one of the common causes of failure with the crop is insufficient cultivation. The first cultivation frequently is necessary before the beans are up if the soil is heavy and forms a hard crust after a rain. A light harrowing should be given as soon as possible after the crust forms in order to break the crust and allow the beans to come up, and at the same time destroy the young weeds. Various methods are employed in breaking the crust. The rotary hoe is used with marked success in many sections; the spike-toothed harrow is, perhaps, more generally used; and the weeder is often employed.

A light harrowing has been found beneficial when the crop is planted, drilled broadcast, or in rows. Experience has shown that to harrow the drilled or broadcast crop will result in larger yields of hay, and also harrowing the crop planted in rows will reduce later work with the cultivator. In using the harrow,

the teeth should be slanted slightly backward and the cultivation should be diagonally across the rows.

In general, soybeans planted in rows are cultivated with the ordinary corn cultivators. Under favorable conditions the soybean germinates in a few days, and cultivation should begin as soon as the seedling plants appear. One deep cultivation may be given as for corn but afterwards the cultivations should be shallow. Cultivation should be frequent enough to keep down the weeds, and continue until the plants are ready to bloom (Fig. 22). Many blossoms will be destroyed where branches are more or less broken, and the yield of seed reduced if cultivation is continued beyond that stage. Moreover, soybeans

Fig. 22.—Last cultivation of soybeans.

should not be cultivated when they are tender from rain or dew as the plants are easily broken or bruised. Level cultivation is preferable as the harvesting can be more easily accomplished.

In the Orient, the first weeding and cultivation take place when the seedlings reach a certain height. The field is weeded and cultivated two or three times during the growth of the plant. Although most of the cultivation is accomplished by hand, a crude one-horse plow of the single shovel type is used.

Soybeans in Mixtures.—The soybean may be satisfactorily grown in combination with other farm crops. Although the chief advantage is a better balanced ration, the mixtures give a larger yield and also a greater variety of forage. The combin-

ing of soybeans with other crops for forage is rapidly gaining favor, thus indicating the advantages of different combinations.

Soybeans and Cowpeas.—Soybeans and cowpeas make a very satisfactory mixture for hay or pasture and the yield is nearly always greater than that of either crop alone. In this mixture tall, strong-growing varieties of soybeans are desirable as they

Fig. 23.—Soybeans and sorghums grown in mixture for forage purposes.

tend to support the vining cowpeas. Varieties of these crops having about the same maturity should be selected.

In sowing a mixture it is essential to have more soybean plants than cowpeas so that the vining growth of the cowpeas may be supported properly. One bushel of soybeans and one-half bushel of cowpeas will give excellent results if drilled broadcast; if planted in three-foot rows, about one-half of this

quantity is sufficient. The seed can be sown best with an ordinary grain drill, whether it is to be in rows or broadcast.

The time for cutting the hay will depend on the relative stages of growth of the two crops. As nearly as possible, both plants should be at that stage of growth giving the best quality of hay. This time is when the soybean seed is about full grown and the first pods of the cowpeas are ripe. The harvesting and curing of a mixture of cowpea and soybean hay is more easily accomplished than of cowpeas alone, and slightly more difficult than in the case of soybeans alone.

Fig. 24.—A field of soybean and Sudan grass grown in mixture for hay.

Soybeans and Sorghums.—Soybeans grown in combination with sorghums (Fig. 23) make an excellent hay, soiling, or ensilage crop. The tall-growing varieties of soybeans, like the Virginia, Arlington, or Wilson-Five and either the Amber or Orange varieties of sorghums are preferable. This mixture is, perhaps, most satisfactory in cultivated rows, as the sorghum is apt to choke out the soybeans when broadcasted, unless the sorghum is planted thinly. When sown in rows, about 15 lb. of sorghum and 45 lb. of soybeans per acre will be sufficient.

Soybeans and Sudan Grass.—Sudan grass is an excellent crop for growing in combination with soybeans (Fig. 24). Not only is a better yield but a better-balanced forage obtained, as the Sudan grass is low and the soybean high in protein. The best results are to be obtained by broadcasting, planting about 50 lb. of soybeans and 10 lb. of Sudan grass to the acre. This mixture

is cut for hay about the time the soybean seeds are nearly full grown. This hay is easily harvested and cured.

Soybeans and *Johnson Grass.*—Johnson grass, as well as Sudan grass, is excellent for growing in mixtures with soybeans. The same methods of combining Sudan grass and soybeans apply to a Johnson grass and soybean combination.

Soybeans and Millet.—Soybeans and millet are not especially recommended as a mixture. The millet matures too early for any of the good forage varieties of soybeans.

Fig. 25.—A field of soybeans and corn grown in the same row for ensilage.

Soybeans and Corn.—Soybeans are more generally grown with corn than with any other crop (Fig. 25). The mixed crop is sometimes pastured but usually cut and ensiled. When the object is to secure a mixed silage of corn and soybeans, various methods are employed, but the three in most common practice are:

1. Planting the soybeans in separate fields from the corn. When filling the silo, loads of corn are cut alternately in the ratio of one load of soybeans to three of corn.

2. The soybeans and corn are planted in alternate rows, or

two rows of corn and one of soybeans. These are then harvested and cut into the silo together.

3. The easiest, least expensive, and perhaps the most common method is to mix the corn and soybean seed when planting. With this method the planting is all done at one operation and the crop may be cared for as commonly practiced. In different sections the manner and rate of seeding differ somewhat. In Wisconsin the usual method employed is to mix the corn and beans in equal quantities and regulate the planter to drop seeds at about twice the ordinary rate for planting ensilage corn. Occasionally the corn is planted in check rows at the usual distance and afterward the soybean seed is planted between the corn hills with a hand planter, dropping about five seeds to the hill. Another method of mixing the seed is to add to the regular seeding of ensilage corn 6 to 8 lb. extra of soybean seed per acre.

Under conditions where corn grows tall and leafy, much larger yields of soybeans can be secured in separate fields. Where the soil and climate will permit, it would lessen the cost of production to grow the soybeans with the corn. Results obtained by Minns (1912) at the Cornell Experiment Station do not favor the planting of the two crops together as the beans are apt to be crowded out in competition with the corn. It would appear that the harvesting and maintaining of the desired proportions of beans and corn could be more certainly accomplished by growing the two separately.

Soybeans have been considered especially for use with corn to increase the protein content of the silage. Comparing corn and soybeans grown separately as well as combined in the drill, Hartwell (1920) found in Rhode Island that an insufficient proportion of beans was obtained by planting the two crops together in the same drill. It is suggested that when the desirable proportion of one part of beans to three parts of corn is required for the silo, the two crops should be planted separately. Noll and Lewis (1921) in a series of experiments in Pennsylvania found that soybeans grown with corn for ensilage did not give increases in yield of total material over corn alone. In only two years out of six did the soybeans comprise more than 5.2 per cent. of the total green weight. The presence of 10 per cent. or more of soybeans with the corn appreciably increases the percentage of protein in the silage.

Soybeans, Sunflowers and Corn.—Bergh (1920) in Minnesota has recommended a mixed crop of corn, sunflowers and soybeans for silage. In growing the mixed crop the seed was used in the following proportion: Corn, 3 parts; sunflowers, 1 part; soybeans, 1 part; and planted at the rate of 20 lb. per acre, drilled in rows 40 in. apart with a corn planter. This produced a larger tonnage than either corn or sunflowers planted alone.

CHAPTER VI

HARVESTING AND STORAGE OF SOYBEANS

Soybeans present no especially difficult problems in harvesting by machinery. Several special types of machine have been devised for harvesting and thrashing soybean seeds, which reduce greatly the cost of production. With good care soybean seed can be stored for long periods without loss. Unlike most other beans, they are rarely injured by weevils.

Harvesting Soybeans for Hay.—The soybean when cut at the right stage of growth and properly cured makes an excellent hay of high feeding value and is greatly relished by all kinds of live stock. The use of this hay as a source of protein, which can be grown on the farm, to balance feeds for growing livestock or for milch cows, should reduce the quantity of high-priced concentrated feeds which it is necessary to purchase.

Time of Cutting.—The soybean may be cut for hay at any time from the setting of the seed until the leaves begin to turn yellow. It is most suitable for hay, however, when the pods are well-formed for at this stage of growth the largest yield and the best quality of hay will be obtained. If the crop is cut earlier, the percentage of protein will be higher but the total yield will not be so large and the difficulty of curing much greater. If the cutting is delayed, however, the stems become more fibrous and decline in feeding value, and if left too long, much loss in leaves will occur. The variation in the composition of hay of the Mammoth Yellow variety cut at different stages of development is shown in the following table:

Table XXVIII.—Composition of Hay of Mammoth Soybean at Different Stages of Development. Arlington Farm, Virginia

Stage of growth	Moisture, per cent.	Protein, per cent.	Fat, per cent.	Nitrogen-free extract, per cent.	Fiber, per cent.	Ash per cent.
Full bloom..........	5.11	19.22	1.45	38.56	26.50	9.16
Pods forming........	5.35	12.72	1.06	42.50	30.82	7.55
Seed half developed...	5.40	10.31	2.34	44.73	30.45	6.77
Seed fully developed..	5.30	15.94	7.83	38.76	25.97	6.20

Curing Soybean Hay.—Although some experience is essential to cure soybean hay properly, those who have cured cowpea hay will find that of the soybean much more readily and easily cured. Under promising weather conditions, the cutting may begin as soon as the dew is off the plants and continue for the rest of the day. The plants should be allowed to lie in the swath until the leaves are thoroughly wilted, but great care should be exercised to rake them before the leaves become dry and brittle. After raking into windrows, the plants should be left for a day or two, depending on the weather. The hay can then be placed in small cocks or bunches. Five or six days of good curing weather

Fig. 26.—Soybean hay on frames. Under unfavorable weather conditions hay can be successfully cured in this manner.

is ample time for making good soybean hay. Most of the curing is done in the shocks which if well put up, will withstand considerable wet weather without damage. Great care should be used to prevent the loss of leaves, as these are a most valuable part of the plant.

Under unfavorable weather conditions, curing frames or poles with cross pieces can be used to good advantage (Fig. 26). These frames are usually three or four-sided pyramids made of boards or poles 3 to 6 ft. long, fastened together at the top and held by cross pieces near the base. With these frames a hollow shock is formed, thus allowing the free circulation of air which lessens the danger of spoiling and secures better curing. Although the hay should, as a general rule, be in a well-wilted condition when placed in the frame, well-cured hay has been obtained by placing the crop on the frames as soon as cut.

Soybean hay should be thoroughly cured before it is stacked or housed. The hay may be placed in good-sized stacks or under cover. When stacked in the open it is essential that grass or some other material that sheds rain be placed over the stack. In stacking the hay, poles or logs placed in the center of the stack so as to leave passages for air will greatly lessen the danger of spoiling.

Shrinkage in Curing.—During 1915, 1916 and 1917, a series of experiments was carried out at Arlington Experiment Farm to secure data on which to base a sampling system that would give greater accuracy and insure the investigator of results in spite of weather conditions for field curing in forage experiments with the soybean. Ten pound samples of green material were taken in duplicate from plots cut for hay yields. In taking the samples, the work was done as quickly as possible, to avoid loss in weight by evaporation. Burlap bags were used to receive all samples and each sample was marked with a tag bearing a number and other data necessary for identification. The samples were stored in a favorable place to facilitate drying and at the same time were given protection from rain.

Table XXIX gives the results obtained with ten varieties of soybeans ranging from the early, Black Eyebrow, to the very late, Barchet.

Table XXIX.—Comparison of the Loss in Moisture in 10-lb. Samples of Green Forage of Ten Varieties of Soybeans when Air Dried. Arlington Farm, Virginia

Variety	1915, per cent.	1916, per cent.	1917, per cent.	Average of 3 yrs., per cent.
Austin	74.4	78.4	77.5	76.8
Arlington	78.1	78.4	77.5	78.0
Barchet	73.7	75.0	72.8	73.8
Black Eyebrow	75.5	80.0	78.6	78.0
Chiquita	73.7	75.0	74.7	74.5
Mammoth	75.9	73.1	72.2	73.7
Midwest	74.4	77.5	74.4	75.4
Tokio	74.1	73.7	72.2	73.3
Virginia	75.3	79.5	75.9	76.9
Wilson	75.6	76.6	75.6	75.9
Average	75.1	76.7	75.1	75.6

Yields of Soybean Hay.—The soybean will yield from 1 to 3 tons of hay to the acre and occasionally 4 tons, depending upon the quality of the soil and the favorableness of the season. Under favorable conditions soybeans should average at least 2 tons to the acre. Yields of hay of important varieties secured at various experiment stations in the United States are given in table XXX on p. 89.

Harvesting for Silage.—Soybeans may be used for silage any time from the appearance of the first bloom until the pods are full grown, the best results, however, being obtained if the plants are cut when the pods are about one-half filled. The crop may be harvested with a side-delivery reaper or with a twine binder. The latter implement is, perhaps, the best and most satisfactory as the beans can be handled in bundles easily and without waste.

Harvesting the Seed.—The character of growth and the uniform maturing habit of the soybean plant contribute to the ease of harvesting the seed. In the United States the harvesting and thrashing is largely accomplished by machinery, that is, where the area planted is sufficient to warrant its use. In Manchuria and Japan the soybean is harvested and thrashed entirely by hand methods.

Time of Harvesting.—The soybean is strictly determinate as to growth—that is, the plants reach a definite size, according to variety and environment, and then mature and die. Nearly all varieties shatter their seeds somewhat, if allowed to stand after reaching maturity. The shattering of the seeds is rather a serious fault and inexperienced growers often sustain heavy losses of seed through lack of knowledge and improper handling of the soybean crop. Special attention is required when the plants approach maturity to prevent serious losses from the shattering of the seed.

When the soybean plant is near maturity, the leaves begin to turn yellow and drop; and before all of the pods are fully mature the leaves, except in a few varieties as the Guelph, have all fallen off. In general, the best time to harvest, except where special bean harvesters are used, is when about nearly all of the leaves have fallen and most of the pods have turned color. If cut at an earlier stage the plants are difficult to cure properly and the yield will be lessened materially on account of the immature grain. On the other hand, if allowed to become

TABLE XXX.—TONS OF SOYBEAN HAY TO THE ACRE AT DIFFERENT EXPERIMENT STATIONS IN THE UNITED STATES

	Aksarben	Biloxi	Black Eyebrow	Chestnut	Chiquita	Elton	Early Brown	Ebony	Habaro	Haberlandt	Hamilton	Ito San	Mammoth	Manchu	Mandarin	Mikado	Medium Green	Midwest	Morse	Peking	Tokio	Tarheel Black	Virginia	Wilson	Wis. Black
Arkansas	...	1.6	1.2	...	1.9	...	1.0	...	...	1.5	...	1.1	1.7	0.9	...	1.5	...	1.2	...	1.9	1.7	2.1	1.7	1.7	
Connecticut	...	...	...	...	...	...	...	...	...	...	...	1.3	...	...	...	...	1.6	1.3	...	1.6	...	...	...	1.7	
Delaware	...	...	...	2.4	2.9	2.1	...	1.9	1.8	2.9	...	1.6	...	2.1	...	3.2	...	2.0	2.7	2.4	...	...	...	2.6	
Georgia	0.9	1.8	...	...	1.5	...	...	1.2	...	2.1	...	0.7	1.9	...	...	...	...	...	...	1.1	0.9	1.5	1.1	1.1	
Illinois	...	...	2.1	...	...	2.4	...	2.7	...	2.9	2.8	2.2	2.1	1.9	...	3.1	1.8	...	...	2.7	...	3.0	...	1.7	
Indiana	2.6	...	2.3	...	...	2.3	...	...	2.1	2.5	2.2	2.2	...	2.4	1.9	1.7	...	2.1	2.1	2.0	...	...	1.7		
Iowa	2.1	...	2.2	1.9	...	2.1	2.1	2.0	2.2	2.5	2.1	2.0	1.5	2.1	1.4	1.7	2.3	2.3	2.7	2.4	...	...	1.8	2.4	1.7
Kansas	1.7	...	1.2	1.6	...	...	...	1.2	...	1.9	2.4	1.6	...	1.6	0.8	...	...	2.8	...	2.2	...	...	2.0		
Louisiana	...	3.0	2.0	...	...	...	...	...	...	...	...	...	...	2.0	...	...	...	...	...	1.5	3.0	2.5	2.0	2.0	
Maryland	...	...	...	...	...	...	...	3.8	...	2.8	...	...	3.0	...	...	...	...	...	2.5	3.1	...	...	3.1	2.8	
Michigan	3.5	...	2.4	...	...	3.8	2.3	...	...	...	2.9	2.5	1.0	2.9	2.8	...	2.1	2.4	...	2.6	...	...	2.5	2.1	1.6
Minnesota	...	...	...	2.7	...	2.5	...	...	2.7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2.2
Mississippi	...	...	...	...	...	...	...	...	...	1.1	...	2.0	2.2	...	...	...	1.5	2.6	...	1.7					
Missouri	...	...	...	2.0	...	1.6	...	2.4	1.9	2.3	2.3	1.7	...	1.6	...	2.4	...	...	2.4	...	...	...	2.4	2.0	2.0
N. Hampshire	...	...	...	...	...	...	...	1.9	...	2.6	...	2.4	2.1	...	...	...	2.6	1.9	...	2.1	...	...	...	2.3	
N. Jersey	...	...	...	...	...	0.6	...	1.0	...	0.8	1.2	0.8	...	0.7	...	...	...	...	...	...	...	...	0.9	1.1	
N. Carolina	...	...	0.7	...	1.6	...	...	...	...	1.1	...	...	1.5	0.7	...	...	...	...	...	1.2	1.2	2.0	1.2	1.0	
Ohio	...	...	...	...	...	...	...	2.3	...	...	2.4	2.3	...	...	...	...	2.6								
Pennsylvania	...	...	2.0	...	...	2.6	2.2	...	...	2.8	2.5	2.2	2.0	...	1.6	1.9	2.5	2.2	...	1.9	...	...	3.0	2.4	
Tennessee	2.0	...	...	...	...	...	...	...	...	2.6	...	1.8	3.2	...	...	...	1.3	...	...	...	3.8	3.2	2.3		
Vermont	...	...	...	...	...	...	...	...	...	...	...	2.8	2.8	...	...	...	3.2	3.4	...	3.0	...	...	...	2.9	
Virginia	...	...	1.0	1.8	2.7	2.2	...	1.4	...	2.9	...	1.5	1.8	...	...	...	1.8	1.9	...	2.2	2.6	...	1.8	2.0	
W. Virginia	2.2	...	1.7	...	...	2.0	...	...	...	2.5	2.1	1.9	...	2.1	...	2.3	2.3	...	...	2.4	...	...	2.6	2.4	
Wisconsin	...	...	1.4	1.4	...	1.6	1.6	1.1	...	...	...	1.5	1.2	1.6	1.4	1.9	2.1	...	...	...	...	...	2.4	...	1.5

too ripe the pods will shatter before the plants are mowed and much seed will be lost. When special harvesters are used to gather

FIG. 27.—A field of mature soybeans ready to cut for seed.

FIG. 28.—Harvesting soybeans for seed with a bunching attachment on the mower.

the seed, the plants must reach full maturity to obtain the best results (Fig. 27).

The stage of maturity to which the plants should be allowed to grow varies also with regard to season and variety. In a hot,

dry fall the plants should be cut at an earlier stage than in a cool, moist fall. A few varieties, however, can be left with little or no loss of seed until time of maturity in any season.

In the Oriental countries the plants are pulled or cut usually just before the pods are mature so as to prevent loss of seed by shattering.

Method of Harvesting.—Many methods of harvesting the crop are used in different sections where the soybean is grown largely for seed production. When the cutting is done with a mowing machine, it is well to have a side-delivery attachment

FIG. 29.—Self-rake reaper used in cutting soybeans for seed.

(Fig. 28) in order that the horses will not need to trample on the swath of cut beans. If cut with a mower without such an attachment, however, the plants should be removed at every round out of the way of the team, for if trampled upon many of the seeds will be shelled out and wasted.

The self-rake reaper (Fig. 29) has given very satisfactory results, as the cut plants are placed in bunches out of the way of the machine and team.

The self-binder can be used to good advantage with the taller growing varieties of beans if the plants are not too coarse. This method of harvesting is coming rapidly into favor in many sections. For the best results with this machine the plants should be cut while some of the leaves are still retained, as the plants will cut more easily and no loss will result from shattering.

The bean harvester which is used to a slight extent in the northern states is mounted on wheels like a riding cultivator. It has knives that can be adjusted to run just beneath the surface

of the ground, cutting the plant where it is soft. This machine will cut two rows at a time and place both in a windrow for curing and convenient for handling. To do good work, the cutting

FIG. 30.—Soybeans cut for seed with binder and bundles placed in shocks for curing.

knives must be kept sharp; otherwise the plants will be pulled out by the roots instead of being cut off.

Small areas may be cut with a scythe, corn knife, or sickle.

FIG. 31.—The ordinary gasoline thrashing outfit may be used in thrashing soybeans.

In some sections comparatively large acreages are cut in this manner.

Methods of Curing and Handling.—When cut with a mowing machine with an attachment or with a self-rake reaper, the

plants may be raked in small piles or placed in small shocks. These piles or shocks should be left for four or five days in good drying weather, or until the grain is found to be fairly dry in the pods. Wet weather does not injure the crop seriously provided the plants are not allowed to rest on the wet ground too long at a time. If rain occurs, the piles should be watched carefully and turned frequently. Where a binder is used, the bound bundles should be shocked eight or ten to a shock and allowed to remain until thoroughly dry (Fig. 30).

Hay caps are not necessary when the piles or bundles are shocked properly. They may remain in the field until thrashing time or if thoroughly dry may be housed and thrashed later.

The cured crop is ordinarily loaded on wagons in the field by hand, but the single drum web loader commonly used for haying will do the work more rapidly and with less loss of seed than the hand methods.

Thrashing.—The ordinary grain separator (Fig. 31) can be adjusted to thrash soybeans successfully, but as equipped for small grains a large percentage of cracked beans will result. The chief cause of split beans is the high speed of the cylinder which should be reduced at least one-half, but the speed of the fan and other parts of the separator should be maintained. This may be accomplished by doubling the size of the cylinder pulleys. In some cases a special set of thin concaves is used, while in other instances some of the concaves are removed. Good judgment on the part of the thrasherman will enable him to adjust the ordinary separator so that the beans may be thrashed with practically no splitting. Some manufacturers have special pea and bean hulling attachments for grain separators, which are said to do very satisfactory work. These attachments may be added to the ordinary separator at a small cost.

Special pea and bean separators of different sizes are now on the market. These types of machines do clean hulling and split practically none of the beans. Undoubtedly such separators are more satisfactory and economical where a considerable acreage of beans is grown.

Soybeans, if thoroughly dry, can easily be thrashed with a flail. If one has only a small acreage—an acre or so—this method is practicable and economical. In some sections of eastern North Carolina, a thrashing table is employed. This table is merely a rough board affair, with a top consisting of two inch pieces about

two inches apart. The table is placed on a large canvas in the field between the rows of cut beans. Bundles of beans are placed on the table and the seed beat out with strong sticks or poles. With two men carrying the bundles and two beating out, from 50 to 75 bu. can be thrashed out in a day.

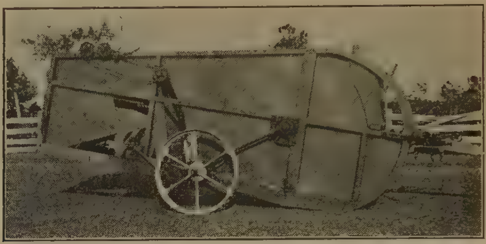

FIG. 32.—A special bean harvester used in gathering the soybean seed from the standing mature plants and also cleaning it.

In a few sections a corn shredder has been used to advantage. If properly cured and dried, the beans shell out very readily with this machine.

Special Bean Harvesters.—The harvesting of seed from the mature standing vines by means of patented bean harvesters,

FIG. 33.—A special bean harvester by which the plants are cut, thrashed, and cleaned.

of which there are several types (Figs. 32, 33) is rapidly gaining in popularity in sections where the soybean is grown rather extensively for seed. The commonest type is a two-wheeled, box-like machine and is drawn by two horses (Fig. 34). As the machine passes over the row of plants, four sets of rapidly revolving arms or long teeth on a large revolving cylinder like the cylinder of a separator shatter the beans from the pods into the body of the harvester. As the machine moves up the row, the seed is constantly raked by a man to the rear of the box. As

the seed box becomes filled, the seed is removed and the pods and broken stems are screened out. To secure the best results the rows should be ridged, though recently patented machines are suitable either for ridged or level rows. One of the types of machines also has a cleaning arrangement. Under favorable conditions, two men with a team can harvest one acre in about two hours by this method. Although there is some loss of beans, it is more than compensated by the saving of time and labor.

Seed Yields.—In regard to the seed yield of the soybean, there is considerable variation in the figures given by authorities in different countries. In Manchuria bean experts estimate the yield from 1,100 to 1,600 lb. to the acre, commercial authorities from 1,600 to 1,800 lb., and Japanese agricultural experts

Fig. 34.—A special bean harvester used to gather soybean seed from the standing mature plants, and which can be adjusted to level or ridged cultivation.

from 400 to 2,000 lb. In the best bean-producing districts the average yield is said to be more than 1,800 lb. to the acre. The average yield of soybeans to the acre in Japan for the decade 1904–1913 is 15.7 bu. The highest average yield, 21.6 bu. is recorded on the west or Japan Sea coast, while the lowest average yield, that of the Soochoo Islands, is 8.48 bu.

In South Africa at the Government Experiment farms as high as 2,000 lb. per acre were recorded, while in many instances the yield was well over 1,000 lb. to the acre.

When grown alone for seed, the best varieties under proper culture in the United States yield from 30 to 40 bu. of seed to the acre. A maximum yield of 50 bu. to the acre has been reported from North Carolina. Seed yields of the more important varieties grown in the United States, as reported by investigators at various Experiment Stations, are shown in Table XXXI. It will be seen that the yields vary greatly

TABLE XXXI.—BUSHELS OF SOYBEAN SEED TO THE ACRE AT DIFFERENT EXPERIMENT STATIONS IN THE UNITED STATES

State	Aksarben	Black Eyebrow	Biloxi	Chiquita	Ebony	Elton	Habaro	Haberlandt	Hamilton	Ito San	Mammoth	Manchu	Midwest	Mikado	Med. Green	Morse	Mandarin	Peking	Tokio	Tarheel Black	Wilson	Virginia
Alabama	14.3	....	18.8	....	12.3	....	....	15.0	....	6.6	....	....	....	....	....	....	....	15.9	10.4	4.5	8.9	15.1
Arkansas	....	7.4	....	11.8	....	....	....	8.4	....	8.4	11.6	7.2	9.9	8.2	7.0	5.8	....	9.9	10.7	9.7	11.5	10.5
Connecticut	....	....	....	....	26.6	....	....	....	....	24.9	....	....	24.8	14.8	23.8	19.1	....	16.7	....	....	20.2	....
Delaware	....	23.6	....	15.3	25.2	19.2	23.9	23.3	....	21.9	....	19.2	28.6	22.2	15.2	35.0	....	32.7	17.9	8.4	32.2	29.0
Georgia	11.0	....	11.6	9.4	6.9	....	....	11.2	....	8.3	16.7	....	....	....	....	....	....	11.0	11.9	12.7	10.0	13.5
Illinois	....	32.6	....	....	32.1	39.5	....	32.5	....	29.3	....	36.1	28.2	....	34.9	38.2	22.5	22.1	....	....	35.8	33.0
Indiana	20.4	18.9	....	....	23.9	20.2	17.0	21.5	17.4	18.5	15.5	19.2	16.6	20.2	21.9	20.7	19.8	18.2	....	....	....	22.7
Kansas	22.5	18.7	....	....	....	....	....	20.5	....	18.1	....	22.8	19.7	....	....	....	11.7	17.9	....	....	....	20.0
Kentucky	....	15.9	....	....	17.0	....	....	20.2	....	14.9	18.0	....	20.6	....	....	17.8	....	17.8	....	....	18.4	19.8
Maryland	....	....	....	....	17.1	....	....	15.9	....	10.1	9.9	....	14.0	....	....	13.7	....	15.0	....	....	14.7	18.4
Minnesota	....	....	....	....	....	18.5	19.8	....	....	....	....	....	....	....	....	....	20.1	....	....	....	....	....
Mississippi	....	....	27.1	....	....	....	....	20.5	....	10.5	36.6	....	13.3	....	14.6	....	....	23.3	....	16.6	....	....
Missouri	....	14.5	....	17.9	22.3	19.8	20.3	25.4	22.2	19.8	11.7	20.5	19.0	22.9	....	23.6	....	15.3	14.3	....	21.1	23.1
Nebraska	19.1	17.9	....	....	....	....	13.6	15.6	....	....	....	....	....	....	....	....	13.3	....	....	....	....	....
N. Jersey	....	....	....	....	15.5	16.6	....	15.8	18.0	15.3	....	19.9	16.7	....	13.7	....	....	....	....	19.2	17.7	19.2
N. Carolina	....	11.4	....	18.5	....	....	....	13.5	....	....	22.5	11.3	....	....	....	....	....	11.6	18.5	20.5	13.5	13.5
Ohio	....	22.1	....	....	24.9	26.6	24.5	....	25.0	21.4	....	22.0	23.9	18.0	23.7	....	....	12.3	....	....	....	....
Pennsylvania	....	19.0	....	....	22.3	24.9	....	20.0	20.4	18.1	....	23.2	19.1	12.0	21.9	....	15.7	12.9	....	....	19.9	16.0
S. Carolina	....	....	....	....	....	....	....	7.1	....	4.5	10.8	....	....	....	....	....	....	....	6.7	....	....	10.4
S. Dakota	10.6	7.7	....	....	....	....	....	....	....	....	....	11.8	....	....	....	....	10.9	....	....	....	....	....
Tennessee	....	....	....	....	19.8	....	....	25.7	....	20.2	23.9	....	25.9	....	16.5	....	....	....	....	....	....	....
Virginia	....	....	....	14.9	17.5	20.0	....	27.3	....	19.7	21.2	....	24.6	....	21.6	....	....	17.9	20.6	....	21.0	21.2
Washington	....	10.2	....	....	....	....	....	....	....	8.6	....	18.8	....	....	....	....	8.9	....	....	....	....	....
W. Virginia	26.9	28.1	....	....	....	30.3	....	36.9	30.5	....	....	28.9	....	29.2	31.9	....	....	31.4	....	....	28.8	34.9
Wisconsin	....	26.1	....	....	....	19.9	....	....	....	23.3	....	24.0	16.3	....	21.3	....	25.9	....	....	....	....	....

with the same variety at different stations. This in most cases may be attributed to the adaptability of the variety to certain localities for seed production. In general the figures given represent the average yield for a number of years, and indicate the best seed-producing sorts.

Proportion of Straw to Seed.—The proportion of straw per bushel of grain has been worked out by Williams and Park (1917) of the Ohio Experiment Station, the data being obtained from 5-year average yields of seed and straw. In the following table it will be noted that the highest seed yielders have a comparatively low proportion of straw to seed.

TABLE XXXII.—RELATIVE YIELDS OF STRAW TO SEED IN DIFFERENT VARIETIES OF SOYBEANS. OHIO EXPERIMENT STATION

	Yield per acre, 5-year average		Pounds of straw per bu. of seed	Ratio of straw to seed
	Seed, bu.	Straw, lb.		
Sable	14.01	2,292	164	1:2.7
Taha	19.88	2,786	140	1:2.3
Cloud	18.34	2,510	137	1:2.3
Yosho	19.28	2,262	117	1:1.9
Hamilton	23.49	2,636	112	1:1.8
Mikado	19.85	2,114	106	1:1.7
Amherst	23.12	2,390	103	1:1.7
Auburn	22.22	2,110	95	1:1.6
Midwest	24.06	2,278	95	1:1.6
Ito San	21.17	1,956	92	1:1.5
Ebony	23.78	2,166	91	1:1.5
Medium Green	23.87	2,185	91	1:1.5
Habaro	23.70	2,134	90	1:1.5
Ohio 9001	24.00	1,964	81	1:1.4
Ohio 9016	29.22	2,236	77	1:1.3
Elton	26.51	1,906	72	1:1.2

Storing Soybean Seed.—The storage of soybean seed requires special care. The massing of large quantities of beans in deep bins or other poorly ventilated receptacles should be avoided, as heating, which is likely to occur, will ruin the germination. Unless the grain is thoroughly dry when thrashed, it should be placed in shallow bins or on the floor for a time, where good ventilation is afforded. This will allow the beans to pass

through the sweat without heating. The condition of the seed, in any case, should be noted occasionally in order to detect any tendency to heat. If it should show any such signs, it should be removed at once, and spread out until thoroughly dry. If the seed is thoroughly dry when ready for storage, it may be put into burlap or other loosely woven sacks, and stacked up in a well ventilated place. In stacking the sacks of seed, two are placed parallel to each other with a space between and the next two laid across these in the opposite direction. This gives more space and better ventilation. Soybeans are seldom attacked by weevils, as are cowpeas, but when a seed house becomes badly infested with these insects, they will attack almost any grain, including soybeans. They may be destroyed by carbon bisulphide.

Fig. 35.—Method of storing soybean seed awaiting shipment in Manchuria. The beans in sacks are stacked under Chinese mats.

Even when properly stored, soybean seed loses its viability rather rapidly (see Table XXXIII). As a rule it is not advisable to plant seed more than 2 years old without first testing for germination.

Various methods are employed in Manchuria for storing the seed, one of the most common of which is shown in Fig. 35.

Separation of Cracked from Whole Soybean Seed.—Frear (1922) at the Missouri Experiment Station has had some success in separating cracked from whole soybean seed. The principle of the method is that whole, round beans will roll down a slanting surface, and jump across an opening, while broken, flattened beans will slide down and drop through the opening in the slanted surface. By careful adjustment it is said most of the cracked beans can be removed from the whole beans. However, it is almost impossible to remove all of the whole beans from the cracked beans that go through the opening. Quite successful

results have been obtained by using the spiral vetch separator in separating cracked from whole soybean seed.

Viability of Soybean Seed.—The seeds of the soybean do not retain their viability well, and it is not advisable to sow seed 2 years old without previously testing. Unless care is exercised in properly curing and storing, soybean seeds are apt to heat and thus quickly have their viability destroyed. A small percentage of the seed will, under favorable conditions, retain its viability four or five years, and this has been found to vary according to variety, as shown in the following table:

TABLE XXXIII.—VIABILITY OF SOYBEAN SEED

Variety	Seed color	Date of germination test				
		9 mos., per cent.	1 yr. 5 mos., per cent.	2 yrs. 1 mo., per cent.	3 yrs. 2 mos., per cent.	4 yrs. per cent.
Chernie	Black	94.0	90.0	76.5	66.0	46.5
Shanghai	Black	99.0	94.0	93.0	70.0	43.5
Baird	Brown	97.0	93.0	88.0	65.0	24.5
Fairchild	Black	95.5	93.0	84.5	66.0	20.0
Jet	Black	92.5	89.5	60.0	60.0	19.5
Habaro	Straw yellow	95.5	94.5	78.5	48.0	6.5
Shingto	Olive yellow	100.0	97.0	91.0	49.0	5.0
Cloud	Black	95.5	81.0	53.5	9.0	4.5
Ebony	Black	94.0	91.0	71.5	25.0	4.0
Tashing	Green	90.5	88.0	81.5	34.0	3.0
Ito San	Straw yellow	100.0	93.0	83.0	45.0	2.5
Guelph	Green	97.5	94.5	86.5	14.0	1.5
Mammoth	Straw yellow	77.0	40.0	32.5	24.0	0.5
Haberlandt	Straw yellow	76.0	19.0	2.5	1.0	0.0
Meyer	Black and brown	95.0	87.5	71.0	25.0	0.0

Pedigreed, Inspected, Registered and Certified Seed.—Several states have formed seed improvement associations, the object of which is to specialize in the production and marketing of high yielding, adapted pure seed. Seed stock which is descended from an individual plant or group of plants of which a performance record has been kept is termed "*Pedigreed Seed.*" "*Registered Seed*" is pedigreed seed that has successfully passed both the field and final inspections conducted by the State Crop Improvement Association under the supervision of the State Agricultural College. Seed of varieties or strains of crops which in tests conducted by the State Agricultural College have demonstrated their adaptability, purity and yielding qualities and have

passed *both* field and final inspections is termed "*Certified Seed*"

Indiana.—The certification of seed of soybeans shall be based upon a preliminary inspection of the crop in the field while in the pod before harvest, and a second inspection of a 2-quart sample of the respective seed which shall be sent by the grower to the Secretary of the Crop Improvement Association. All certified grain must contain less than ½ of 1 per cent. of of discernible mixture of other varieties. The habit of growth of the soybean shall be noted to ascertain the probable variety in case of doubt. Whenever a field under inspection indicates by its habit of growth that it is not of the variety specified by the grower, the question should be settled by the inspector, and if the correct name can be applied to it, it shall be certified, but if the variety cannot be ascertained it shall not be certified.

Wisconsin.—One inspection, usually by a county agent, is made in the field while the soybeans are growing. Later, a general inspection is made by sending college representatives or having the county agent select and send a sample to the college. All soybeans must germinate 90 per cent. or above, and the seed must be plump and sound in every respect.

Virginia.—The requirements governing inspection are that the field must be grown from registered or certified seed stock. Field inspections are made some time during the 3 weeks preceding harvest of the crop. The fields must be rogued and cleared, all obnoxious weeds pulled and must show less than 1 per cent of disease transmissible on the seed. In final inspection the seed must have less than ½ of 1 per cent. foreign material, less than ½ of 1 per cent. of apparent mixtures of other varieties, must germinate 90 per cent. or more, must be 92 per cent. or more of large, whole seed, must show a purity of at least 99 per cent. and conform to the State seed law, and must not contain more than one in 200 of any weed seed. The seed should be hand-picked to eliminate mixtures of foreign varieties.

Varieties: Black Eyebrow, Wilson, Virginia, Hollybrook, Mammoth Yellow, Tokio, Mammoth Brown, Haberlandt.

Ohio.—The requirements for field inspection are that soybeans must be true to variety name, and must not contain more than 1 per cent. of mixture with other varieties. Requirements for certified soybeans are that the soybean seed must be recleaned, practically free from split beans, free from all weed seeds, and must germinate 93 per cent. or more.

Varieties: Manchu, Midwest, Ito San, Elton, Hamilton, Medium Green, Peking, Wilson, Virginia.

Michigan.—The Michigan Crop Improvement Association inspects three varieties of soybeans: Manchu, Black Eyebrow, and Ito San. One inspection is conducted in the field within three weeks of harvest time. The other inspections are made afterwards of the thrashed beans. The grower after thrashing submits an uncleaned sample, and from that it is determined whether or not the beans are suitable for cleaning. The seed is sent then to the Farm Bureau Seed Department, which is the official sales agent for the Association, and it is cleaned there under inspection by the Association.

For the Registered Seed grade, which is seed suited for the further production of Pedigreed seed, soybeans must contain not more than one mixture in 2 lb., must be of good color and appearance, weigh not less than 58 lb., be free of weeds and any considerable amount of foreign material and germinate better than 90 per cent. Certified seed which is seed of those varieties suited for ordinary crop production, must conform to these same standards with the exception that it needs to be only 99.8 per cent. pure as to variety.

CHAPTER VII

COMPOSITION OF THE SOYBEAN

Although the composition of the soybean plant has been studied by many investigators, especially in the United States, it has been principally with regard to the nutritive value of the forage. The soybean plant differs quite markedly from other plants ordinarily used for forage in its greater content of nitrogen, oil, and mineral substances. Lechartier (1903) has, perhaps, made the most extensive investigations relative to the nutritive and mineral constituents of the different parts of the plant. The proportions of the different parts of the plant, according to Lechartier, are shown in Table XXXIV.

Table XXXIV.—Proportions of Stems, Leaves and Pods

Percentage of the Different Parts of the Soybean Plant. After Lechartier

	Plant 1, per cent.	Plant 2, per cent.	Plant 3, per cent.	Average, per cent.
Stems	27.13	23.12	26.82	25.45
Leaves	35.00	42.44	42.72	40.18
Pods	37.87	34.44	30.46	34.37

COMPOSITION OF PLANT

Nutritive Constituents.—The percentages of the nutritive materials contained in each part of the plant is shown in Table XXXV.

TABLE XXXV.—NUTRITIVE CONSTITUENTS CONTAINED IN EACH PART OF THE SOYBEAN PLANT. AFTER LECHARTIER

	Green				Dry			
	Stems, per cent.	Leaves, per cent.	Pods, per cent.	Entire plant, per cent.	Stems, per cent.	Leaves, per cent.	Pods, per cent.	Entire plant, per cent.
Proportion	25.45	40.18	34.37	100.00	26.87	41.33	31.78	100.00
Water	18.62	29.38	25.98	73.98				
Nitrogen (total)	0.05	0.19	0.26	0.50	0.21	0.71	1.00	1.92
Protein (crude)	0.34	1.15	1.63	3.12	1.29	4.43	6.24	11.96
Nitrogen (materials)	0.27	1.03	1.38	2.68	0.83	3.98	5.29	10.10
Amides (asparagin)	0.09	0.14	0.18	0.41	0.34	0.53	0.82	1.69
Fat	0.07	0.42	0.57	1.06	0.28	1.62	2.18	4.08
Carbohydrates	2.19	2.39	2.34	6.92	8.29	9.25	8.98	26.52
N-free-extract	1.33	3.49	1.38	5.20	5.01	13.50	5.29	23.80
Cellulose	2.84	1.91	1.87	6.62	10.81	7.39	7.48	25.38
Ash	.....	.....	.....	......	1.29	5.09	2.08	8.46

The composition of the different parts of the plant varies considerably as the plant approaches maturity. The following table shows the percentage of nutritive constituents of the different parts of the plant from the time of the bloom until the plant reaches full maturity.

TABLE XXXVI.—COMPOSITION OF THE DIFFERENT PARTS OF THE SOYBEAN PLANT AT DIFFERENT STAGES OF GROWTH, AT ARLINGTON FARM, VIRGINIA[1]

	Moisture, per cent.	Protein, per cent.	Fat, per cent.	N-free-extract, per cent.	Fiber, per cent.	Ash, per cent.
Roots:						
Full bloom	5.33	9.31	0.76	32.66	45.76	6.18
Pods ½ grown	5.21	8.76	0.93	32.88	46.85	5.38
Plants mature	4.91	3.59	0.56	27.00	59.09	4.85
Stems:						
Full bloom	4.72	10.44	0.56	35.43	43.31	5.54
Seed ½ grown	3.82	12.34	0.45	34.97	43.67	4.75
Plants mature	4.84	3.33	0.67	30.86	57.72	2.58
Leaves:						
Full bloom	5.72	19.56	2.08	49.85	14.65	8.14
Seed ½ grown	6.04	19.56	2.61	47.06	14.87	9.86
Pods:						
Seed ½ grown	5.57	18.53	1.50	41.03	25.31	8.06
Plants mature	6.53	5.26	1.40	45.01	35.61	6.19
Seed:						
Seed ½ mature	5.84	37.38	12.02	30.45	8.07	6.24
Plants mature	5.36	37.56	18.61	29.28	4.64	4.55

[1] Analyses made by Bureau of Chemistry, U. S. Department of Agriculture.

Mineral Constituents.—In studies of the mineral constituents of the plant, Lechartier found that the leaves and stems both contain some phosphoric acid. During the maturing of the plant the formed phosphates passed from the leaves to the pods and then to the seeds which contain the greatest proportion.

The proportion of sulphuric acid was found to decrease in passing from the stems to the leaves to the pods and finally to the seed where it attains its minimum.

Calcium was found to accumulate especially in the leaves which contain six times as much as the pods. Magnesium is found everywhere with calcium although it is not as abundant as calcium in the seed.

Potassium was found to be concentrated in the young pods from whence it goes into the seed during the formation of the seed. The proportion of potassium to calcium is 7 to 1 in the seed, 3 to 1 in the pods, but in the leaves there is 4 to 5 times as much calcium as potassium.

The composition of the different parts of the plant changes during the period of ripening according to the emigration of different elements towards the seed. Lime and magnesium increase in the stems and leaves, while potassium concentrates in the seeds.

The total weights of mineral materials contained in 1,000 kilos (2,204 lb.) of dry forage are given in the following table.

TABLE XXXVII.—TOTAL WEIGHTS OF MINERAL MATERIALS IN 1,000 KILOS[1] OF DRY FORAGE. AFTER LECHARTIER

Mineral Materials	Stems, kilos	Leaves, kilos	Pods, kilos	Entire plant, kilos
Proportion	26.90	41.35	31.75	
Ash	12.91	50.87	20.50	84.28
Silica	0.07	1.46	0.12	1.65
Phosphoric acid	1.24	1.58	3.33	6.14
Sulphuric acid	2.24	2.61	1.71	6.56
Calcium	3.33	18.37	2.47	24.17
Magnesium	1.91	5.40	2.16	9.47
Potassium	2.13	4.01	7.45	13.59
Sodium	0.20	0.07	0.89	1.16
Nitrogen	2.05	7.08	10.00	19.13

According to Joulie, the mineral materials contained in 1,000 kilos (2,204 lb.) of soybean plants in the dry state are as shown in Table XXXVIII.

[1] Kilo = 2.2 lb.

TABLE XXXVIII.—MINERAL MATERIALS IN 1,000 KILOS[1] OF DRY FORAGE. AFTER JOULIE

Mineral materials	Stems and leaves, kilos	Seeds, kilos	Entire plant, kilos
Nitrogen	12.50	57.88	28.10
Phosphoric acid	4.62	17.39	9.02
Sulphuric acid	2.72	1.41	2.26
Calcium	43.65	3.28	29.81
Magnesium	9.58	8.91	9.36
Potassium	9.76	20.29	13.39
Sodium	4.13	0.50	2.88
Iron Oxide	1.27	0.93	1.15
Silica	32.73	1.03	21.83

In the following table are shown the percentages of the phosphoric acid, potash, and nitrogen contained in the different parts of the plant from the time of bloom until maturity.

TABLE XXXIX.—PERCENTAGES OF NITROGEN, PHOSPHORIC ACID AND POTASH CONTAINED IN DIFFERENT PARTS OF THE SOYBEAN PLANT AT DIFFERENT STAGES OF GROWTH, AT ARLINGTON FARM, VIRGINIA[2]

	Moisture, per cent.	Nitrogen, per cent.	Potash, per cent.	Phosphoric acid, per cent.
Roots:				
Full bloom	3.41	1.40	0.60	0.32
Pods ½ grown	3.82	1.05	0.50	0.26
Pods full grown	3.58	0.96	0.47	0.22
Plants mature	3.91	0.64	0.22	0.11
Stems:				
Full bloom	4.00	1.83	1.21	0.46
Pods ½ grown	3.79	1.80	0.91	0.41
Pods full grown	4.35	1.08	1.17	0.26
Plants mature	4.27	1.01	0.58	0.22
Leaves:				
Full bloom	5.40	3.59	1.28	0.56
Pods ½ grown	5.78	3.18	0.97	0.50
Pods full grown	7.05	2.16	0.75	0.34
Plants mature				
Pods:				
Pods ½ grown	4.62	3.56	2.12	0.87
Pods full grown	5.62	1.29	1.90	0.26
Plants mature	5.56	1.25	1.23	0.25
Seed:				
Pods ½ grown	3.90	5.95	1.80	1.28
Pods full grown	4.77	6.51	1.82	1.36
Plants mature	4.48	6.37	1.89	1.38

[1] Kilo = 2.2 lb.

[2] Analyses made by Bureau of Chemistry, U. S. Dept. of Agr.

Forms of Nitrogen in Soybean Nodules.—According to Stroud (1921) an examination of 100 gm. of soybean nodules failed to show the cyanide radical by a method sensitive to 0.01 mg. of hydrocyanic acid. Of the total nitrogen in nodules, 30 to 40 per cent. is water soluble and 40 to 55 per cent. salt or dilute alkali. About 3 per cent. of the water-soluble nitrogen was protein or proteose. No globulin and only a small amount of albumin was found. Primary amino nitrogen formed 16 per cent. of the protein-free water-soluble nitrogen, and amide nitrogen 19.3 per cent. Over 60 per cent. of the total water-soluble nitrogen was precipitated by phosphotungstic acid.

Composition of Seed.—Extensive investigations have been made by American and European chemists relative to the composition of the seed of the soybean. The seed differs from that of other legumes not only by its anatomical structure but also by its chemical composition. The differences in composition from other legumes are principally in nitrogenous substances, in oil, and in the almost entire absence of starch. The following table shows the composition of the soybean compared with others of the most important legumes.

TABLE XL.—COMPOSITION OF SOYBEAN SEED COMPARED WITH THAT OF OTHER LEGUMES[1]

Legume	Moisture, per cent.	Protein, per cent.	Fat, per cent.	N-free extract, per cent.	Fiber, per cent.	Ash, per cent.
Soybean	9.9	36.5	17.5	26.5	4.3	5.3
Cowpea	11.6	23.6	1.5	55.8	4.1	3.4
Field pea	9.2	22.9	1.1	57.8	5.6	3.4
Navy bean	13.4	22.7	1.5	53.0	5.8	3.6
Horse bean	12.6	26.2	0.9	49.4	7.1	3.8
Velvet bean	11.7	20.8	6.4	51.0	7.5	2.6
Garden pea	11.8	25.6	1.6	53.6	4.4	3.0

The numerous analyses of seed of different varieties indicate that the composition varies with the variety. Analyses made of over five hundred distinct sorts by the United States Department of Agriculture show a range of from 12 to 24 per cent. fat and 30 to 46 per cent. protein. Wide varietal differences are shown in amounts of starch, iodine value, and ash. The

[1] HENRY and MORRISON, Feeds and Feeding.

following table shows the differences in composition of a few of the best known American varieties.

TABLE XLI.—COMPOSITION OF COMMON AMERICAN VARIETIES OF SOYBEANS[1]

Variety	Fresh or air-dry material					
	Moisture, per cent.	Protein, per cent.	Fat, per cent.	N-free extract, per cent.	Fiber, per cent.	Ash, per cent.
Mammoth	7.49	32.99	21.03	29.36	4.12	5.01
Ito San	7.42	34.66	19.19	27.61	5.15	5.97
Haberlandt	8.67	36.59	20.55	24.41	4.00	5.78
Guelph	7.43	33.96	22.72	25.47	4.57	5.85
Midwest	8.00	35.54	19.78	26.30	4.53	5.85
Kingston	7.45	36.24	18.96	26.28	4.79	6.28

The various constituents, according to numerous analyses are very unequally divided in the different parts of the seed. The following table gives the percentage composition of the different parts of the soybean seed.

TABLE XLII.—PERCENTAGE COMPOSITION OF THE DIFFERENT PARTS OF SOYBEAN SEED. AFTER LECHARTIER

Part of seed	Proportion of the seed	Dry matter	Nitrogenous substances	Carbohydrates	Fat	Ash
Entire seed	100	90.18	38.06	12.06	17.80	4.44
Cotyledons	90	89.43	41.33	14.60	20.75	4.38
Embryo	2	87.99	36.93	17.32	10.45	4.08
Seed coat	8	87.47	7.00	21.02	0.60	3.83

Protein.—The protein content of the soybean ranges from about 30 to about 45 per cent. in the different varieties tested by the U. S. Department of Agriculture. The proteins of the soybean and its products differ quite markedly from those of other legumes not only in amount but in the character and the variety and amounts of amino acids which they yield on digestion.

According to the extended investigations by Meissl and Böcker (1883), the soybean contained the following proteids: A so-called "casein" (27.6 per cent.), albumen (0.5 per cent.), a proteid precipitated by cupric acid and potassium hydroxid (2.5 per cent.),

[1] Tennessee Agricultural Experiment Station.

and, in addition a very small amount of non-albuminoid nitrogenous substance.

Osborne and Campbell (1897) give as a result of their study of the proteids of the soybean the following:

1. The chief protein is a globulin, glycinin, differing from legumin in containing twice as much sulphur, 0.4 per cent. more carbon, and 0.5 per cent. less nitrogen. Its composition is as follows:

Carbon	52.12
Hydrogen	6.93
Nitrogen	17.53
Sulphur	0.75
Oxygen	22.63

2. A very small amount of a more soluble globulin resembling phaseolin.
3. An albumin-like protein, legumelin (0.5 per cent.).
4. A small quantity of proteose.

The hydrolysis of the protein, glycinin, according to investigations by Osborne and Clapp (1907) yielded the following amino acids which are compared with those of cow's milk. The protein of the soybean is very similar to that of cow's milk.

Table XLIII.—Percentage Composition and Comparison of the Amino Acids of the Protein of the Soybean and of Cow's Milk

	Soybean	Cow's milk
Glycine	0.97	0.00
Alanine	not isolated	
Valine	0.63	7.20
Leucine	8.45	9.40
Proline	3.78	6.70
Phenylalamine	3.86	3.20
Aspartic acid	3.89	1.40
Glutanic acid	19.46	15.55
Serine	not isolated	0.50
Trysonine	1.86	4.50
Argnine	5.12	4.84
Histidine	1.39	2.59
Lysine	2.71	5.95
Ammonia	2.56	1.61
Tryptophane	present	1.50

These investigators point out that the proportion of amino-acids in glycinin is thus not very different from that found in animal flesh and approaches it more closely than does that of the amino-acids in the protein of wheat and other cereals. Meissl and Böcker (1883) refer to the glycinin as "vegetable casein" and call attention to the points it has in common with animal casein. It is acted upon by strong acids and ferments and gives the same products as animal casein with these agents.

Some Japanese investigators found in the soybean as much as 6.9 per cent. of albuminoid nitrogen. The protein of the soybean yields on digestion a complete amino-acid mixture. Osborne and Mendel (1917*b*) found that rats will grow very nearly normally on glycinin. It was also proven by these investigators that cystine, lysine, and tryptophane had to be added to any protein that does not contain them in order to make it growth-promoting. It will be noted in the preceding table that the soybean has these. In another series of investigations, Osborne and Mendel (1917*c*) proved that the proteins of the soybean, unlike those of other leguminous seeds thus far investigated, are adequate for promoting growth. It also was found by these investigators (1917*a*) that if the protein of corn, which lacks the above amino acids, was supplemented with the protein of the soybean, growth of rats was satisfactory.

In a series of experiments to determine the presence of creatinin in various legumes, Oshima and Ariizumi (1914) found it to be present in the soybean in small amounts.

Carbohydrates.—Many investigators have studied the nitrogen-free extract of the soybean from various points of view. In many cases, the published analytical data are somewhat conflicting. The soybean has a variety of carbohydrates, altogether amounting to from 22 to 29 per cent., depending on the variety and maturity of the bean. The most complete quantitive separation of the carbohydrates existing in the soybean has been made by Street and Bailey (1915). Table XLIV gives the constituents contained in the nitrogen-free extract as found by these investigators.

Considerable differences of opinion have existed among investigators with regard to the presence of starch in soybeans. Blondell (1888) and Prinsen (1896) did not find any starch. Meissl and Böcker (1883) after an extended study of the soybean reported starch, the amount found being less than 3 per cent. The

Table XLIV.—Percentage Composition of the Nitrogen-free Extracts of the Soybean

Galactan	4.86
Organic acids	1.44
Pentosan	4.94
Invert sugar	0.07
Sucrose	3.31
Raffinose	1.13
Starch	0.50
Cellulose	3.29
Undetermined hemicelluloses	0.04
Waxes, color principles, tannins, etc. (by diff.)	8.60
Dextrin	3.14
Total	31.32
Galactan from raffinose	0.24
Per cent. nitrogen-free extract	31.08

starch grains are described as being extremely small and as differing in form from the typical pea or bean starch. Hanausek (1884) also discovered grains of starch in the soybean, embedded in the fat in the adjoining cells where the surface of the cotyledons meet, and according to the author, could not be detected by the usual chemical methods. Japanese chemists have not identified starch in the native soybean. Undoubtedly the discrepancies relative to starch content have been due to the maturity of the beans or rather the method in which they are allowed to mature. Harz (1885) found that where the beans do not mature thoroughly or when allowed to mature after the vines were cut, starch may be present, some varieties being more likely to contain it than others. If the beans are thoroughly mature, they are practically starch free. Stingl and Morawski (1886) found a very small quantity of starch, the formation of which they attributed to a very active diastase.

Thoroughly mature seed of sixteen varieties of soybeans grown quite generally throughout the United States were submitted by the authors to Dr. Albert Mann of the United States Department of Agriculture for investigation as to starch content. Dr. Mann reported that in all cases where starch reaction was obtained, it appeared upon the inner (approximate) surfaces of the two cotyledons. It was intensest at the middle part of the line of separation and extended immediately under or behind the epidermal layer of these two surfaces. In the major-

ity of cases only a trace of starch extended back into the thicker portion of the cotyledons, that is, midway the inner and outer surfaces. One variety, the Hahto, showed a distribution of starch throughout most of the cotyledon, although the color reaction was nowhere intense. No starch was found in the seed coats of any of the varieties and only a mere trace in the embryos. It will be noted in the following table that those varieties with black or brown seed coats (with the exception of the Black Eyebrow variety) are practically starch free while a general tendency toward relatively high starch content is exhibited by the yellow-seeded sorts.

Table XLV.—Starch Content of Commercial Varieties of Soybeans in the United States

Variety	Seed color	Amount of starch
Peking	Black	No starch.
Virginia	Brown	No starch.
Wilson	Black	No starch or merest trace.
Biloxi	Brown	Trace.
Early Brown	Brown	Small amount.
Hollybrook	Straw yellow	Small amount.
Guelph	Green	Small amount.
Midwest	Straw yellow	Thin area covering ¾ of inner surface.
Ito San	Straw yellow	Similar to Midwest but the areas heavier in starch.
Manchu	Straw yellow	Strong starch areas in inner surface of each cotyledon.
Mammoth	Straw yellow	Decided starch band on inner surface of each cotyledon.
Black Eyebrow	Black and olive	Pronounced starch band on inner surface of each cotyledon.
Hahto	Olive yellow	Starch grains more or less through the cotyledons.
Chiquita	Straw yellow	Very strong starch band on inner side of each cotyledon.
Haberlandt	Straw yellow	Very strong starch bands on inner side of each cotyledon.
Tokio	Olive yellow	Strongest starch reaction of all varieties tested.
Easy Cook	Straw yellow	Decided starch bands on inner surface of each cotyledon; more or less starch to outer side of cotyledons also; starch more or less distributed through the tissue of the bean.

Levallois (1881) reported the presence of 9 to 11 per cent. of material soluble in alcohol but which did not reduce Fehling's solution. According to Li Yu Ying and Grandvoinnet (1911–12) it does not reduce Fehling's solution at once but only after boiling with mineral acids. When treated with nitric acid this material yielded some acetic acid and mucic acid. Tollens (1888) calls this substance galactan. Maquenne is of the opinion that this sugar material is perhaps galactan which gives galactose by hydrolysis and some mucic acid by oxidation. Schulze and Frankfurt (1894) proved the presence of cane sugar in soybean seed. Street and Bailey (1915) found only 3.31 per cent. of cane sugar in the Hollybrook (Midwest) variety. They also found 5.73 per cent. of reducing matter after hydrolysis of the malt extract, of which 2.59 per cent. was found to be galactan and pentosan combinations. The remaining 3.14 per cent. was considered as dextrin, vegetable gums and mucilages. Stingle and Morawski (1886) reported the presence of about 2 per cent. of a mixture of different sugars which could be readily fermented. They state that the sugar found in the soybean bears the closest analogy to lactose. This sugar ferments rapidly and entirely in the presence of the yeast of beer and gives some glucose. Maxwell (1890) identified paragalactin, an insoluble carbohydrate.

Pentosans have been found to vary with the variety, ranging from a trace to over 4 per cent. Borghesani (1907) found 3.86 per cent. while Street and Bailey (1915) found 4.94 per cent. Some varieties of soybeans have been found to contain small amounts of raffinose, the Hollybrook (Midwest) containing 1.13 per cent. according to Street and Bailey (1915). Bowers (1919) found 0.37 of 1 per cent. in a sample of commercial soybean meal.

Enzymes.—The presence of various enzymes in the soybean has been reported and studied by several investigators. Takeuchi (1909) made a special study of urease which acts specifically upon urea, liberating ammonia. Practical analytical use of it has been made in the form of standardized urease. Kennaway (1920) describes in detail a method, designed particularly for the estimation of urea in blood serum by soybean urease.

Wester (1916) from results of study concludes that the ureolytic action of soybeans is not due to bacterial action. Results of investigations by De Graaff and Van der Zande (1916) led

these authors to conclude that although bacteria may be present in soybeans, this is not invariably the case. *Urobacillus pasteurii* could not be isolated. The strong ureolytic action of the soybean cannot be attributed solely to bacteria, since sterile beans still possess a very strong urea-splitting power, and, therefore, a urease must be present.

According to Onodera (1915) the urease of soybeans loses its activity on dialysis. The lost activity is restored by the addition of a small amount of fresh urease, indicating that the fresh urease contains a coenzym. The inhibitory effects of heat, acid, and alkali are exerted upon the coenzym, but not upon the urease proper. In germination urease accumulates in the germs of soybeans in large proportion, but free coenzym is absent. Wester (1920) found that the action of urease on soybean extract changes considerably when kept at 37°. The urea number (*i.e.* the number of mgr. of urea converted by the urease solution) was 126 on the first day, but after 7 days standing it had been reduced to 47 and after 14 days to 38.2 and had increased after 21 days to 90, declining after 26 days to 85, and after 35 days to 60.3.

In a study of a number of varieties of soybeans, as to the urease activity, Dox (1920) reports that some difference exists, but that this difference appears to bear no relationship to the germinating power of the seed or the protein content of the latter. It was demonstrated that urease was present in seeds that were practically dead. In regard to the best temperature to secure greatest activity, above 50° and probably below 60° were reported. Wester (1919) determined the urease content of about 48 varieties of soybeans and found all of the beans, whether old or fresh, possessed strong enzym action. Annett (1914) tested the urease activity of different varieties of soybeans and found urease present in all varieties.

In the preservation of urease, Robinson and Oppenheim (1919) found that camphor in 0.25 per cent. suspension preserved the activity of the soybean urease for at least 45 days, a much longer period than that of tolüol or other preservatives.

Stingl and Morawski (1886) report extended investigations with an amylolytic enzyme, diastase. When a small quantity of this diastase was used the starch was transformed into two-thirds sugar and one-third dextrin, whereas the enzyme of barley malt gives much less glucose and much more dextrin

when the quantity of malt is small. In 1880, a patent was taken for the use of the soybean in the manufacture of a yeast. Bertrand and Riokind discovered a glucoside, vicianin, and an enzyme capable of effecting its hydrolysis. In studies on enzymes of the soybean, Street and Bailey (1915) found a protease of the peptoclastic type, a peroxidase, and a lipase but negative results were obtained for sucrease and protease of the peptonizing type. No attempt was made by these investigators to examine the material for urease or to corroborate the presence of the glucoside-splitting enzyme but the presence of an active amylase was corroborated. The lipases of the castor bean and soybean were studied by Barton (1920) with respect to their ranges and amounts of activity in an aqueous solution and to their action on lard, olive oil, and ethyl butyrate. From the results it was concluded that both soybeans and castor beans contain the same lipase or lipases but in different quantity. The castor bean lipase was found to be more intense in its action than the soybean lipase, but both reacted within the same ranges of acidity.

Fat.—According to Matthes and Dahle (1911) soybean fat or oil contains 15 per cent. of palmitic acid and 80 per cent. of liquid acids. The latter are stated to consist of about 70 per cent. of oleic acid, about 24 per cent. of linolic acid and about 6 per cent. of linolenic acid. The unsaponifiable matter was found to contain about 55 per cent. of a crystalline portion consisting of 2.4 per cent. of stigmasterol. Lewkowitsch (1904) states that this stigmasterol is undoubtedly identical with Klobb and Bloch's (1907) soyasterol melting at 169°C. The unsaponifiable matter (45 per cent.) was found to consist of unsaturated oxygenated compounds.

Meissl and Böcker (1883) in their studies found the oil to contain no free fatty acid and to consist almost entirely of neutral triglycerids. At a low temperature or on standing a long time the palmitin and stearin triglycerids were precipitated in crystalline form. It was found that one gram of soybean fat required 191.8 mg. of potassium hydroxide for saponification. They examined the fat extensively with reference to its iodin absorption. The figures obtained for the iodin value of a large number of varieties range from 121 to 141.

Lewkowitsch (1904) emphasizes the fact that soybean fat does not give the Halpen reaction which is so characteristic of

cottonseed oil. A small percentage of cottonseed oil in soybean oil can be detected by means of Halpen's test, as has been frequently ascertained in the case of soybean oil adulterated with cottonseed oil where the market prices favored such adulterations. Settinj (1912) considers the following reaction as characteristic for soybean oil: When 5 c.c. are treated with 2 c.c. of chloroform and 3 c.c. of a 2 per cent. aqueous solution of uranium nitrate, the mixture yields, on shaking, an intensely lemon yellow-colored solution.

For the direct identification of soybean oil, Newhall (1920) describes a modification of the one suggested by Settinj. The color test used by Newhall consists in mixing 5 c.c. of chloroform with 5 c.c. of the oil, a few drops of gum arabic solution and 5 c.c. of a 2 per cent. solution of uranium nitrate or acetate. On shaking thoroughly, a characteristic lemon-yellow emulsion is formed with all samples of crude and refined imported soybean oil, but not with bleached and deodorized bean oil, hydrogenated oil, bean oil fatty acid, or with any other oils thus far tested. The test has been found of value in the detection of admixture of the cheaper bean oil with wood oil or linseed oil. In the former case it has been found possible by comparison with standards of varying amounts of pure wood oil and pure bean oil to detect as small an amount as 5 per cent. of the bean oil. It is pointed out that the test has been used only with imported oils and may be characteristic of only certain varieties of soybean.

Thompson and Morgan (1912) have made rather an extensive study of the oil from different varieties of the soybeans. The oil was of a light amber color, showing little variation although the beans were of almost all shades of color from light yellow to black, indicating that little if any of the coloring matter of the skin was extracted by the solvent. The constants obtained from the different varieties showed little variation, although some of the varieties were of widely different types. The maximum, minimum, and average of the more important constants for forty-eight varieties are shown in Table XLVI:

Table XLVI.—Maximum, Minimum, and Average of the More Important Constants of Soybean Oil from 48 Varieties, Compared with Those of Other Wellknown Oils

	Specific gravity (15°)	Saponification value	Iodine value
Maximum	0.9235	195.40	138.96
Minimum	0.9108	174.08	114.01
Average	0.9193	187.27	129.72
Linseed	0.9316	192.00	180.00
Cottonseed	0.9230	192.00	108.00
Corn	0.9274	191.90	125.90

The constants obtained by Holland (1908) are compared in the following table with those of other observers. It will be noted that although different methods were used in the extraction of the oil and the beans were probably grown under widely different climatic conditions, the agreement for the different constants is quite close.

Table XLVII.—Comparison of the More Important Constants of Soybean Oil by Different Observers

Observer	Specific gravity (15°)	Saponification value	Iodine value
Holland	0.9206	191.95	130.77
Morgan	0.9193	187.27	129.72
Morawski and Stingl	0.9270	192.90	122.20
De Negri and Fabrus	0.9242	192.50	121.30
Shukoff	0.9240	190.60	124.00

Further determinations were made by Thompson and Morgan (1912) using a composite made by mixing equal quantities of each of the 48 samples of oil representing different varieties. The following table gives the results of these determinations.

Table XLVIII.—Constants for Soybean Oil

Specific gravity at 15°C	0.9212
Saponification value	188.65
Acid value	0.28
Reichert-Meissl value	5.3
Hehner value	93.50
Neutralization value	177.82
Iodine value of oil	127.78
Iodine value of unsaturated fatty acids	131.93

TABLE XLVIII.—CONSTANTS FOR SOYBEAN OIL.—(*Continued*)

Unsaturated fatty acids	84.70
Saturated fatty acids	8.61
Ether number	188.37
Glycerol	10.29
Mean molecular weight	315.5

An investigation was made by White (1919) concerning the possibilities of increasing the unsaturation of vegetable oils, particularly soybean oil, by altering conditions of growth in the plant and by the action of bacteria, enzyms, light, heat, etc. on the oil itself. It was found that the processes of germination and growth of soybeans under different conditions did not alter the amount of unsaturated acids in the ether extracts of such plants. Bacteria isolated from the "foots" of raw linseed oil and enzym extracts from flaxseed and from fresh pig's liver did not increase the unsaturation of soybean oil. Heat, light, and certain catalyzers were almost without effect upon unsaturation. Hydrolysis occurred in most cases, the extent depending upon the presence of moisture in the sample of oil.

Ash.—In view of the importance that is attached to the mineral content of foods several investigators have conducted studies on the ash of the soybean. The ash of the soybean is especially rich in phosphoric acid and potassium as shown in the following table from analyses made by Pellet (1880).

TABLE XLIX.—COMPOSITION OF THE ASH OF THE SOYBEAN SEED. AFTER PELLET

	Sample 1, per cent.	Sample 2, per cent.	Sample 3, per cent.
Potassium (K^2O)	45.02	45.27	45.02
Phosphoric acid (P^2O^5)	29.13	31.92	31.68
Lime (CaO)	8.92	6.50	4.48
Magnesium	8.19	6.48	8.47
Carbonic acid (CO^2)	1.70	1.20	1.00
Sulphuric acid (SO^3)	1.37	4.80	2.74
Chlorine (Cl)	0.75	0.75	0.75
Insoluble	1.10	1.10	1.20
Trace—NaO, FeO	1.59	2.15	4.83
Total	100.17	100.17	100.17
Deducing O^2 for Cl	0.17	0.17	0.17
Total	100.00	100.00	100.00

A series of experiments were carried on by Osborn and Mendel (1917*b*) to determine the mineral content of the soybean seed as related to the growth of young rats. As with other seeds, the soybean was found deficient in the minerals, especially calcium. Data on the mineral content of the soybean in comparison with the seed of three legumes generally used for food, cited by Bowers (1919) is given in the following table:

Table L.—Mineral Content of the Soybean Seed Compared with Those of Cowpea, Navy Bean and Peanut. After Bowers

Legumes	Potassium, per cent.	Sodium, per cent.	Calcium, per cent.	Magnesium, per cent.	Sulfur, per cent.	Chlorine, per cent.	Phosphoric acid, per cent.
Soybean......	2.095	0.380	0.230	0.244	0.444	0.025	0.649
Navy bean...	1.390	0.086	0.235	0.206	0.224	0.047	0.429
Cowpea......	1.636	0.189	0.117	0.243	0.280	0.047	0.532
Peanut.......	0.061	0.563	0.068	0.180	0.254	0.024	0.399

It will be noted in the above table that the soybean is second in calcium, and in phosphorus is by far richer than the others.

Vitamines.—In investigations of the nutritive value of the soybean Daniels and Nichols (1917) studied in a qualitative way the vitamine content. They found that a diet containing 60 per cent. of soybeans, the only source of the vitamines, made possible the production and rearing through the suckling periods two successive litters of young rats. It was also found that rats grew normally on a diet containing 50 per cent. of soybeans, and that the females produced young at an early age.

Other experiments with rats with a view of determining the vitamine value of the soybean were carried on by Osborne and Mendel (1917*b*). A diet of either soybean cake flour or cooked soybean flour, with an added salt mixture of the proper kinds and amounts of different salts, pure starch, butterfat and lard was used. The rats were found to complete their normal growth in the normal length of time. The results indicate that the soybean has a sufficient amount of water soluble vitamine for the promotion of proper growth. The rats grew normally for over 200 days without showing symptoms of nutritive decline, when lard entirely replaced the butterfat. This is much longer than the majority of rats, undergoing experiments for vitamine determination, have grown on a diet without the addition of fat soluble vitamine from some special source like butterfat. This would

seem to indicate that there is in the soybean sufficient of the fat soluble vitamine to promote proper growth. No eye soreness common to rats on a diet lacking sufficient of the fat soluble vitamines was noted. Much better growth was made by rats that had the soybean meal, which did not have the fat extracted than those that had the extracted meal. With the possible exception of flax and millet, the soybean so far as known at the present time is the only seed containing sufficient amounts of both the water soluble and the fat soluble vitamines for the promotion of proper growth.

The Factors Affecting the Oil Content of the Seed.—The percentage of oil in the seeds of soybeans is very unlike in different varieties, and to less degree in the same variety grown in different places. Extensive studies have been made to determine just what factors cause the differences in oil content.

Relation of Oil Content to Stage of Development.—Garner *et al* (1914) in a series of experiments studied the oil content of soybean seeds as affected by the maturity of the plant. Except for the period immediately following blooming and that directly preceding final maturity, there is a fairly uniform increase in oil content, both relative and absolute, throughout the development of the seed, and no evidence was found that there is a critical period of very intense oil formation at any stage of seed development. The oil content of the seeds of the Yokotenn variety gathered at various stages of maturity is shown in the following table:

TABLE LI.—OIL CONTENT OF SOYBEANS GATHERED AT VARIOUS STAGES OF MATURITY

Date harvested	Weight of 1,000 beans, gm.	Moisture in beans, per cent.	Oil in moist beans, per cent.	Oil in 1,000 beans, gm.	Date harvested	Weight of 1,000 beans, gm.	Moisture in beans, per cent.	Oil in moist beans, per cent.	Oil in 1,000 beans, gm.
Aug. 13	3.53	7.50	2.95	0.104	Sept. 11	356.8	6.60	18.05	64.4
Aug. 20	39.3	5.50	10.65	4.19	Sept. 16	447.0	7.55	18.02	80.5
Aug. 23	96.24	5.80	13.40	12.9	Sept. 21	472.3	5.95	18.60	87.8
Aug. 28	146.2	6.10	15.94	23.3	Sept. 25	498.7	7.44	18.37	91.6
Sept. 3	263.7	5.40	16.70	44.0	Sept. 30	487.0	6.35	18.85	90.8
Sept. 6	282.0	6.55	17.00	47.9	Oct. 7	479.3	7.55	17.77	85.2

Relation of Oil Content to Carbohydrate Formation.—As a consequence of the physiological relationship of oil to carbohydrates, it appears that maximum oil production in the plant requires

conditions of nutrition favorable to the accumulation of carbohydrate during the vegetative period and to the transformation of carbohydrate into oil during the reproductive period. As a phase of this relationship between carbohydrate supply and

Table LII.—Oil Content of Soybeans as Affected by Partial Defoliation

Variety and treatment	Date of blooming	Average weight of stalk and root, gm.	Average height of plant, in.	Average yield of beans per plant, gm.	Weight of 1,000 beans, gm.	Moisture in beans, per cent.	Oil in moist beans, per cent.	Oil in 1,000 beans, gm.
Peking:								
Control	July 30	33.7	22.2	56.6	89.8	7.45	16.75	15.0
No. of leaves reduced to about 40 per cent. of normal on June 29, July 16, 22, 30 and Aug. 14	July 30	20.7	19.1	34.1	85.4	6.65	17.52	15.0
No. of leaves reduced to about 50 per cent. of normal at same periods as above	July 30	24.0	20.4	42.2	85.6	7.40	17.80	15.2
Control	July 30	36.8	25.2	51.2	87.1	6.60	17.20	15.0
No. of leaves reduced to about 40 per cent of normal on Aug. 1 and 15	July 30	24.1	21.5	30.7	81.8	6.75	17.85	14.6
Ogemaw:								
Control	July 8	9.7	11.1	24.5	209.0	8.65	16.21	33.9
No. of leaves reduced to about 40 per cent. of normal on July 15 and 30	July 8	5.3	9.7	11.5	168.5	8.55	16.32	27.5
S.P.I. No. 30599:								
Control	July 8	24.5	27.0	61.1	179.4	6.20	19.95	35.8
No. of leaves reduced to about 40 per cent. of normal on July 15 and 30	July 8	16.5	21.5	55.2	167.8	6.25	20.93	35.1
S.P.I. No. 30745:								
Control	July 8	24.5	24.1	58.6	192.6	7.95	19.80	38.1
No. of leaves reduced to about 40 per cent. of normal on July 15 and 22	July 8	16.7	19.2	32.1	180.0	6.05	20.35	36.6
Manchu:								
Control	July 8	27.2	24.4	59.4	190.3	6.70	20.93	39.8
No. of leaves reduced to about 30 per cent. of normal on July 15 and 75 per cent. Aug. 12	July 8	13.5	19.9	33.8	160.4	6.40	21.30	34.2

oil formation in soybeans, it was found that when the normal distribution of the vegetative and reproductive plant parts was modified by partial defoliation (50 to 60 per cent.) the yield of beans was decidedly reduced, but the size of the beans and the oil content were only slightly affected, except in the case of an early maturing variety (Manchu).

Table LII shows results obtained in oil content of soybeans as affected by partial defoliation.

Relation of Oil Content to Number of Pods per Cluster.—On the other hand, the removal of a portion of the blossoms or young pods caused a marked increase in the size of the beans allowed to develop, but did not materially affect the percentage of oil content. The following table shows the oil content as affected by partial removal of very young seed pods:

TABLE LIII.—OIL CONTENT OF SOYBEANS AS AFFECTED BY PARTIAL REMOVAL OF VERY YOUNG SEED PODS

Variety and treatment	Date of blooming	Average weight of stalk and root, gm.	Average height of plant, in.	Average yield of beans per plant, gm.	Weight of 1,000 beans, gm.	Moisture in beans, per cent.	Oil in moist beans, per cent.	Oil in 1,000 beans, gm.
Peking:								
Control	July 30	36.3	25.7	50.2	84.1	6.45	17.15	14.4
Large no. of pods removed Aug. 19	July 30	49.7	27.2	55.0	103.1	6.65	17.69	18.2
Ogemaw:								
Control	July 8	9.7	11.1	24.5	209.0	8.65	16.21	33.9
Larger portion of ods removed July 15 and 22	July 8	9.0	10.8	9.8	204.6	8.00	15.83	32.4
S.P.I. No. 30599:								
Control	July 8	24.5	27.0	61.1	179.4	6.20	19.95	35.8
Larger portion of pods removed on July 15 and 22	July 8	36.2	21.5	52.6	202.2	6.40	20.02	40.4
S.P.I. No. 30745:								
Control	July 8	24.5	24.1	58.6	192.6	7.95	19.80	38.1
Larger portion of pods removed July 15 and 20 and Aug. 19	July 8	38.7	24.2	39.1	227.8	6.35	19.15	43.7
Manchu:								
Control	July 8	27.2	24.4	59.4	190.3	6.70	20.93	39.8
More than ⅜ of pods removed on July 15 and 20 and Aug. 12	July 8	42.1	23.3	25.7	244.4	6.50	19.95	48.8

Relation of Oil Content to Size of Seeds.—There is always lack of uniformity in the size of the seed from an individual plant; but it was found that there was no correlation between the size of the seed and the percentage content of oil as shown in the following table:

TABLE LIV.—OIL CONTENT OF SOYBEANS OF LARGE AND SMALL SIZE SEED FROM THE SAME PLANT

Variety and locality	Size of beans	Weight of 1,000 beans, gm.	Moisture in beans, per cent.	Oil in moist beans, per cent.
Ogemaw:				
Pullman, Wash.	Large	171	5.60	13.88
Pullman, Wash.	Small	106	5.25	14.17
Amherst, Mass.	Large	290	6.30	16.92
Amherst, Mass.	Small	169	6.60	16.63
Wooster, Ohio	Large	259	6.40	16.30
Wooster, Ohio	Small	137	6.40	15.95
Hansen:				
Pullman, Wash.	Large	46	6.10	11.72
Pullman, Wash.	Small	25	5.85	12.27
Statesville, N. C.	Large	64	7.35	13.27
Statesville, N. C.	Small	37	6.80	13.50
La Fayette, Ind.	Large	86	6.75	11.72
La Fayette, Ind.	Small	53	6.75	11.15
Buckshot:				
Kingston, R. I.	Large	364	6.30	17.45
Kingston, R. I.	Small	196	6.65	17.00
Amherst, Mass.	Large	389	6.05	17.87
Amherst, Mass.	Small	215	6.40	16.95

Relation of Oil Content to Length of Life Period.—In another chapter it has been shown that varieties of soybeans show a marked tendency to shorten the time required for reaching maturity when planted late in the season but no correlation was found between the date of planting and the size of the seed or their oil content. These properties appeared to be influenced more by the character than by the length of the growing period. The oil content in several varieties of soybeans planted at stated intervals during the spring and summer months is shown in Table LV:

TABLE LV.—OIL CONTENT OF SOYBEANS PLANTED AT INTERVALS OF TWO WEEKS IN 1911, AT ARLINGTON FARM, VA.

Variety and date of planting	Number of days from planting to blooming	Number of days from blooming to full maturity	Number of days from planting to full maturity	Weight of 1,000 beans, gm.	Moisture in beans, per cent.	Oil in beans, per cent.	Oil in 1,000 beans, gm.
Ogemaw:							
May 1........	40	62	102	186	6.90	17.25	32.4
May 15........	35	58	93	153	7.05	16.38	25.1
June 1........	37	50	87	166	6.90	17.40	28.9
June 15........	32	54	86	145	7.10	17.27	25.0
July 1........	27	58	85	168	7.60	15.51	26.1
Haberlandt:							
May 1........	61	83	144	210	6.65	19.73	41.4
May 15........	54	76	130	211	6.70	19.47	41.1
June 1........	50	74	124	217	6.35	20.32	44.1
June 15........	45	74	119	240	6.80	18.95	45.5
July 1........	44	72	116	244	7.20	17.35	42.3
Buckshot:							
May 1........	40	72	112	271	6.40	19.15	51.9
May 15........	40	69	109	272	6.40	19.62	53.4
June 1........	39	68	107	277	6.20	19.35	53.6
June 15........	39	58	97	250	6.10	18.95	47.4
July 1........	33	64	97	294	6.40	18.43	54.2
Midwest:							
May 1........	56	102	158	329	6.45	17.60	57.9
May 15........	49	94	143	313	6.25	18.25	57.1
June 1........	50	77	127	312	5.70	17.75	55.4
June 15........	45	73	118	305	5.80	17.38	53.0
July 1........	41	66	107	334	6.30	16.43	54.9

Relation of Oil Content to Variety.—It is shown in Table LVI that different varieties of soybeans grown under the same conditions showed marked differences in oil content and very great differences in size of seed.

Table LVI.—Varietal Differences in the Oil Content of Soybeans Grown at Arlington Experiment Farm, Va., in 1907, 1908 and 1910

Variety and year grown	Weight of 1,000 beans, gm.	Moisture in beans, per cent.	Oil in moist beans, per cent.	Oil in 1,000 beans, gm.
Shanghai (S.P.I. #14952):				
1907	215.4	6.65	19.55	42.1
1908	186.1	6.16	18.37	34.2
1910	217.1	6.80	20.20	43.8
Average	206.2	6.54	19.37	40.0
Amherst (S.P.I. #17275):				
1907	193.6	6.65	20.15	39.1
1908	179.3	5.50	19.50	34.9
1910	176.0	6.05	20.33	35.7
Average	182.9	6.07	20.00	36.6
Yokotenn (S.P.I. #19981):				
1907	335.8	6.60	20.67	69.6
1908	311.4	4.85	20.20	62.8
1910	331.9	6.45	21.86	72.8
Average	326.0	5.97	20.91	68.4

Relation of Oil Content to Geographical Location.—In tests with several varieties of soybeans grown under a wide range of conditions there were found differences of more than 100 per cent. in the size of the beans and very large differences in oil content. It is evident, as shown in Table LVII that environment may affect tremendously the size of the seed and the quantity of oil stored therein.

TABLE LVII.—OIL CONTENT OF SOYBEANS GROWN UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

Variety and locality	Weight of 1,000 beans, gm.	Moisture in kernels, per cent.	Oil in kernels, per cent.	Oil in 1,000 beans, gm.
Hansen, (S.P.I. #20409):				
Wooster, Ohio	50.1	5.15	11.90	6.0
Statesville, N. C.	51.0	5.10	12.95	6.6
Pullman, Wash.	39.4	5.95	12.25	4.8
La Fayette, Ind.	72.7	5.15	11.05	8.0
Auburn, Ala.	50.9	6.40	12.38	6.3
Kingston, R. I.	64.5	6.05	12.00	7.7
Buckshot (S.P.I. #17251):				
Wooster, Ohio	251.2	5.85	16.40	41.2
Pullman, Wash.	156.3	5.80	14.55	22.7
La Fayette, Ind.	334.6	6.10	13.25	44.3
Auburn, Ala.	250.4	5.75	20.60	51.6
Kingston, R. I.	347.5	5.70	18.00	62.6
Guelph (S.P.I. #17261):				
Wooster, Ohio	164.0	5.82	16.20	26.6
Statesville, N. C.	269.0	6.12	20.05	53.9
La Fayette, Ind.	190.9	5.32	18.40	35.1
Auburn, Ala.	182.4	5.90	20.90	38.1
Kingston, R. I.	196.1	5.00	17.65	34.6
Ogemaw (S.P.I. #17258):				
Wooster, Ohio	207.4	5.70	16.45	34.1
Statesville, N. C.	193.5	5.15	17.05	33.0
Pullman, Wash.	137.8	5.50	14.40	19.8
La Fayette, Ind.	249.6	6.00	13.70	34.3
Auburn, Ala.	233.3	5.80	19.25	44.9
Kingston, R. I.	235.6	6.05	17.00	40.0

Similar results were obtained in a series of variety experiments by the Office of Forage Crops Investigations, U. S. Dept. of Agric. as to the effect on oil and protein contents of the same variety grown under a wide range of environmental conditions. Table LVIII shows the results obtained with four varieties obtained from Manchuria, comparing the oil and protein content of the original seed with that produced by the same varieties at various experiment stations in the United States.

Extensive tests by Garner *et al* (1914) with soybeans were carried out on different soil types under controlled conditions, using for the purpose large earthen pots set into the ground. The various tests were conducted under a wide range of soil types and

TABLE LVIII.—OIL AND PROTEIN CONTENT OF SOYBEAN VARIETIES GROWN UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

Locality	Weight per 1,000				Oil				Protein			
	36,830	36,847	36,915	37,062	36,830	36,847	36,915	37,062	36,830	36,847	36,915	37,062
Alabama	...	...	...	...	23.3	24.0	22.9	23.5	35.3	32.4	33.1	32.7
Arkansas	200	165	153	139	21.6	21.1	20.0	22.7	33.0	39.0	36.1	36.5
California	166	164	156	141	....	....	....	....	42.0	37.4	37.2	36.8
Florida	171	164	168	158	22.1	20.9	18.8	21.0	35.0	36.1	37.2	35.8
Georgia	161	168	144	129	23.6	22.9	20.4	23.9	30.7	33.5	33.7	32.3
Indiana	...	158	182	146	....	18.0	16.8	17.6	....	41.4	43.1	39.5
Louisiana	207	178	148	127	21.2	21.2	19.6	21.1	39.8	40.2	37.5	39.1
Maryland	196	168	146	...	17.1	17.0	16.7	....	36.7	43.1	42.5	
Minnesota	...	99	143	134	....	16.8	16.0	17.5	....	40.8	41.8	39.4
Missouri	152	177	157	131	20.7	20.2	19.8	20.6	34.5	39.0	38.8	36.1
North Carolina	...	...	...	...	23.0	18.3	19.4	21.5	35.7	41.5	39.5	36.9
Ohio	...	162	143	127	....	18.2	18.0	20.3	....	39.1	40.4	36.8
South Carolina	145	145	140	124	24.7	24.0	22.4	24.4	31.0	32.1	32.6	31.3
Tennessee	235	167	...	127	19.8	19.3	....	20.3	39.3	40.3	....	37.0
Texas	194	198	183	175	17.9	17.6	14.4	18.0	45.7	44.2	43.8	41.3
Virginia (Norfolk)	183	156	134	145	21.2	20.9	21.6	20.9	35.8	37.6	37.8	37.1
Virginia (Blacksburg)	196	152	131	112	17.3	19.1	18.7	19.4	39.6	40.2	39.1	38.6
Wisconsin	...	165	167	137	....	17.3	16.0	16.8	....	40.4	40.0	37.1

(Analyses made by Bureau of Chemistry, U. S. Dept. of Agriculture.)

climatic conditions. The results as a whole emphasize the fact that the relative effects of different soil types are not specific and constant, but depend largely on seasonal conditions. From the data obtained it was concluded that under practical conditions climate is a more potent factor than soil type in controlling the size of the seed and its oil content, probably because those conditions of the atmosphere which constitute the climate largely control the corresponding conditions of the soil. Within ordinary limits the quality of the soil appears to be a minor factor in influencing the size of the seed and its oil content.

Relation of Oil Content to Fertilizers.—In pot-culture tests with soybeans, Garner *et al* (1914) found that the addition of phosphorus increased the oil content but that potassium was without decided effect.

Fellers (1918) at the New Jersey Experiment Station found that the oil content of soybeans decreases in direct proportion to the largeness of applications of lime applied to the soil. The average decrease in oil content due to liming was 2.8 per cent. The oil content of the seed was materially increased with small applications of acid phosphate, especially when the soils were well limed, from 1,000 to 2,000 pounds of lime appearing to be as beneficial as larger applications. A slight decrease in the percentage of oil followed the use of potash. Nitrate of soda caused a decrease in the oil content of soybean seed. Manganese sulfate had little, if any effect upon the oil content of the seed. It happens that the oil content of soybeans is decreased by moderate applications of sulfur, but is increased by large applications. Large applications (600 lb.) of land plaster caused an increase in oil content. The results on the plots where zinc sulfate and ferric sulfate were used, although not conclusive, seemed to indicate a slight decrease in the oil content.

Relation of Oil Content to Nodule Formation.—At the Wisconsin Experiment Station, Woll and Olson (1907) found that the inoculation of the Wisconsin Black variety was followed by a decrease in oil content of the beans. Fellers (1918*a*) at the New Jersey Experiment Station conducted a series of tests on the effect of inoculation on the oil content of the seed. The results showed that inoculating the seed before sowing, or the soil in which the seed was planted, with pure or commercial cultures of *Bacillus radicicola* or well-infected soil, decreased the oil content in direct proportion to the completeness of infection. The

average decrease in oil was 3 per cent. No differences in the drying power of the oil extracted from the seeds of inoculated and uninoculated plants was observed.

Effect of Altitude on Oil Content.—In South Africa, the percentage of oil was found to vary with the altitude. At an altitude of 3,354 ft., the percentage of oil was 20.65; at 500 ft., 21.36; and at 49 ft., 22.19.

CHAPTER VIII

UTILIZATION OF THE SOYBEAN

In the Orient the soybean is grown primarily for the seed. This is largely used for human food and for the manufacture of numerous food products. Much however is crushed for the oil in which case the resulting cake is utilized as feed and as fertilizer.

In the United States the soybean has been employed many years as a forage crop and not infrequently as a green manure crop. The forage is preserved either as hay or ensilage, but pasturing to hogs and sheep is much employed.

In recent years the culture of the plant for seed production has increased rapidly, and the use of the crop will probably develop to far-reaching proportions. The seeds contain about 20 per cent. of a valuable oil. The resulting cake is very rich in protein; valuable both as feed for live stock and for manufacturing meal and flour for human food. The unripe bean seeds form a delicious vegetable while the ripe seeds furnish a very satisfactory substitute for common beans, either boiled or baked.

Diversity of Uses.—The following diagram (Fig. 36) shows the

- Soybeans.
  - Plants.
    - Green manure.
    - Forage.........
      - Hay.
      - Ensilage.
      - Soiling.
    - Pasture.
  - Seeds.
    - Meal...........
      - Human food......
        - Breakfast foods.
        - Diabetic foods.
        - Flour............
          - Bread.
          - Cakes.
          - Muffins.
          - Biscuit.
        - Infant foods.
        - Macaroni.
        - Crackers.
        - Milk.
      - Stock feed.
      - Fertilizer.
    - Oil.............
      - Glycerin.
      - Explosives.
      - Enamels.
      - Varnish.
      - Food products.....
        - Butter substitute.
        - Lard substitutes.
        - Edible oils.
        - Salad oils.
      - Waterproof goods.
      - Linoleum.
      - Paints.
      - Soap stock........
        - Soft soaps.
        - Hard soaps.
      - Celluloid.
      - Rubber substitute.
      - Printing inks.
      - Lighting.
      - Lubricating.
    - Food products..
      - Dried beans.......
        - Soy sauce.
        - Boiled beans.
        - Baked beans.
        - Soups.
        - Coffee substitute.
        - Roasted beans.
        - Vegetable milk...
          - Cheese
            - Fresh.
            - Dried.
            - Smoked.
            - Fermented.
          - Condensed milk.
          - Fresh milk.
          - Confections.
          - Casein.
        - Breakfast foods.
      - Green beans.......
        - Green vegetables.
        - Canned.
        - Salads.

FIG. 36.—Diagram showing the various ways in which the plants and seeds of soybeans are utilized.

manifold uses to which the different products of the soybean are put. Few other plants are useful in so many ways.

Soybeans as Green Manure.—Soils that have become reduced in productiveness through continuous cropping with small grains or other nitrogen-using crops may be restored by the use of leguminous crops such as the clovers, cowpeas, vetches, and the soybean. The value of a crop as a soil restorer depends upon the amount of available plant food which it adds to the soil and also upon the effect which the roots have upon the mechanical condition of the soil. Leguminous plants, through the aid of the root tubercle organisms, are able to add to the available nitrogen of the soil, and hence are extensively used in restoring those deficient in that element.

In general, it is hardly practicable to grow soybeans for a green manure crop alone. That is, the crop is too valuable to plow under for soil improvement except under certain conditions. However, the soybean may follow wheat or oats and make sufficient growth to add considerable organic matter to the soil. The land should not be allowed to be bare during the winter when the crop is plowed under.

Connecticut Results.—The fertilizing value of a crop of soybeans compares very favorably with that of other legumes commonly grown for green manure. At the Connecticut (Storrs) Experiment Station, Woods (1890) made a comparative study of the fertilizing constituents contained in the crop and roots produced on an acre of soybeans, cowpeas, and red clover, as shown in the following table.

TABLE LIX.—FERTILIZING CONSTITUENTS OF SOYBEANS CONTAINED IN CROP AND ROOTS ON ONE ACRE. CONNECTICUT (STORRS) EXPERIMENT STATION

Crops	Green forage, tons	Nitrogen			Potash			Phosphoric acid		
		In crop, lb.	In roots, etc., lb.	Total, lb.	In crop, lb.	In roots, etc., lb.	Total, lb.	In crop, lb.	In roots, etc., lb.	Total, lb.
Soybean......	9.5	165	9	174	109	6	115	42	2	44
Cowpea.......	8.0	67	23	90	60	15	75	17	6	23
Red clover....	13.0	138	44	182	152	32	184	32	13	45

Michigan Experiments.—Some rather extensive experiments were carried on by Smith (1905) at the Michigan Experiment

Station to compare soybeans and other legumes as manures. Taking the approximate yields of the legumes under test as a basis and adding to the fertilizing ingredients in the forage the amounts that would be found in the weight of roots going with that amount of forage, the amounts of nitrogen, phosphoric acid and potash that would be supplied to the soil by the crops of the several legumes, were the entire crop plowed under, are shown in the following table.

TABLE LX.—YIELDS OF HAY OF DIFFERENT LEGUMES AND CONTENT OF FERTILIZING INGREDIENTS. MICHIGAN EXPERIMENT STATION

Legume	Hay, lb.	Nitrogen, lb.	Phosphoric acid, lb.	Potash, lb.
Medium Green soybean	5,860	152.29	27.38	100.89
Ogemaw soybean	3,480	59.03	23.04	29.34
Cowpeas	3,575	61.90	15.45	77.20
Vetch	3,000	77.10	18.58	63.12
Clover, second crop	2,000	51.47	12.05	36.18
Clover, new seeding	2,170	49.06	11.61	63.55

A later experiment was conducted by the Michigan station in which soybeans and cowpeas were sown side by side to compare their values as green manure with that of buckwheat. The yields secured indicated a rather greater value to the soybeans as green manure than the analyses would suggest.

Massachusetts Experiment.—According to results obtained by Goessmann (1896) at the Massachusetts Experiment Station the plowing under of the roots and stubble of soybeans and clover was found to be very advantageous to subsequent crops. However, in a later report (1905) after further tests the results did not indicate a decided benefit following the introduction of the soybean as a crop, and the conclusion was reached that the residual fertilizer left behind by the soybean was comparatively unimportant.

Kansas Data.—At the Kansas Experiment Station, Ten Eyck and Call (1909) report an increase of 14 bu. of corn to the acre where corn followed soybeans in alternate years as compared with corn continuously. At the Arkansas Experiment Station, Newman (1901) found that soybeans used as a green manure gave nearly as good results as cowpeas, as determined

by subsequent crops of wheat, oats, cotton, and corn. With cotton the soybean vines produced a larger yield of cotton than cowpea vines, but the cowpea stubble gave a larger yield than the soybean stubble; with corn, cowpea stubble and soybean stubble yielded the same results, while soybean vines gave better results than the cowpea vines; with oats, the results were slightly in favor of the cowpeas.

In the following table are shown the fertilizing constituents of the roots, stems, leaves, pods, and seed of the Medium Yellow (Midwest) variety cut at different stages of growth.

Table LXI.—Fertilizing Constituents of Soybeans Cut at Different Stages of Growth. Arlington Farm, Virginia

	Nitrogen, per cent.	Potash, per cent.	Phosphoric acid, per cent.	Moisture, per cent.
Roots:				
Full bloom	1.40	0.60	0.32	3.41
Seed half grown	1.05	0.50	0.26	3.82
Seed full grown	0.96	0.47	0.22	3.58
Seed mature	0.64	0.22	0.11	3.91
Stems:				
Full bloom	1.83	1.21	0.46	4.00
Seed half grown	1.80	0.89–0.92	0.41	3.79
Seed full grown	1.08	1.25–1.08	0.26	4.35
Seed mature	1.01	0.58	0.22	4.27
Leaves:				
Full bloom	3.59	1.28	0.56	5.40
Seed half grown	3.18	0.97	0.50	5.76
Seed full grown	2.16	0.75	0.34	7.05
Seed mature				
Pods:				
Seed half grown	3.56	2.12	0.87	4.62
Seed full grown	1.29	1.90	0.26	5.62
Seed mature	1.25	1.23	0.25	5.56
Seed:				
Half grown	5.95	1.80	1.28	3.90
Mature	6.37	1.89	1.38	4.48
Full grown	6.51	1.82	1.36	4.77

Soybeans for Pasturage.—The soybean crop may often be used as pasturage, most profitably, perhaps, when fed to hogs to supplement the corn ration and to sheep (Fig. 37). This is especially desirable when harvesting is interfered with by

lack of labor, bad weather, or other causes, and when the crop is grown for soil improvement. In this way the crop is not only profitable in the feeding value, but also for the fertilizer value from the manure and refuse vines. Hogs greatly relish the bean plant, especially the ripening pods. A considerable part of the growth of young hogs may be made with soybean pasture. Animals ready for fattening may be finished for market much more rapidly if soybeans are used to supplement the corn ration.

Fig. 37.—Pasturing a corn and soybean mixture with sheep. (*Courtesy of Fouts Bros., Camden, Indiana.*)

Feeding Value, Alabama.—In experiments conducted by Gray and Shook (1912) at the Alabama Experiment Station, soybeans, peanuts, chufas, and sorghum were compared as pasturage for hogs. It was found that when corn alone was fed 100 lb. of pork cost $7.63; when fed a two-thirds ration of corn and pastured in addition, 100 lb. of pork cost $8.89 on chufa pasture, $7.79 on sorghum pasture, $3.20 on peanut pasture and $2.74 on soybean pasture. The average gain of the pigs each day on the soybean pasture was 1.02 lb., on the peanut pasture 1.01 lb., on the chufa pasture 0.72 lb., and on the sorghum pasture 0.37 lb. In this experiment the hogs were turned into the soybeans while the pods were very small so that for 2 weeks they ate only the leaves and young shoots.

At the same station, Gray, *et al.* (1911) report 3 years'

work in feeding 105 hogs to determine the value of soybean pasture as compared with other feeds, the most profitable amount of corn to be fed as a supplement and the effect of the soybean forage on the quality of the pork. It was found that when corn was used alone the average daily gain for each hog was 0.375 lb. at a cost of 7.61 cents. When a soybean pasture was grazed with a one-fourth, one-half, and three-fourths ration of corn the average daily gains were raised to 1.102, 1.006, and 1.329 lb. respectively, and the cost of the pork reduced to 2.59, 3.36, and 3.17 cents per pound respectively. One acre of soybean pasture afforded grazing for 10 hogs for 43 days when a one-fourth ration of corn was fed, 48 days on a one-half ration of corn, and 62 days on a three-fourths ration of corn. The total value of pork made on each acre of soybean pasture varied from $25.84 to $39.13.

Feeding Value, Kentucky.—At the Kentucky Experiment Station, Good and Smith (1916) conducted an experiment to determine the relative amounts of gain, as well as the economy of gains, made by pigs pasturing soybeans, with and without a supplementary ration of corn, and when pasturing cowpeas with a supplementary corn ration. The results of the experiment showed that it is not profitable to pasture mature soybeans without a supplementary feed, for only 110 lb. of pork were thus produced to the acre, which valued at $7.00 per hundred-weight, did not pay for the seed sown, cost of cultivation, and rent of land. It was found, however, highly profitable to hog down soybeans if a supplementary feed, such as corn, is given, for the lot of hogs receiving 2 per cent. of its weight in corn meal daily, produced 825 lb. of pork to the acre at a cost of $4.54 per hundred pounds of gain. The net value of pork produced per acre was calculated at $20.32, which, with the value of fertilizer left on the ground, $17.68, would make a total of $38.00. The acre of soybeans hogged off with a supplementary feed of corn produced feed for 10 hogs for 21 days and for 20 hogs for an additional 21 days. The acre of soybeans with no corn fed the hogs produced feed for 10 hogs for 21 days and for 15 hogs for an additional 14 days. It was not found to be profitable to hog down cowpeas, even though they were supplemented with corn meal equal to 2 per cent. of the live weight of the hogs.

Manurial Value, Arkansas.—An experiment was conducted by the Arkansas Experiment Station to determine the effect of the

legume crop grazed by hogs on the two succeeding cotton crops as compared with cotton following corn not grazed. The results showed that the two cotton crops aggregated 2,905 lb. of seed cotton, following peanuts grazed, 2,608 lb. following soybeans grazed, and only 1,802 lb. following corn not grazed.

Feeding Value, Ohio.—At the Ohio Experiment Station, Robison (1920) found that the rate of gain and the concentrate requirement per unit of gain of pigs on soybean pasture varied with the amount of concentrates fed. Full fed pigs given a high protein supplement gained more rapidly and ate fewer pounds of concentrates for each pound of gain produced than others given only corn as a concentrate. In the case of limited feeding the use of tankage did not increase the rate of gain nor lower the concentrate requirement per unit of gain. Two lots of pigs fed corn alone and corn and tankage on soybean pasture gained more rapidly and required fewer pounds of concentrates per unit of gain than either of two lots similar fed on sweet clover pasture. A small amount of tankage with corn proved beneficial for feeding pigs on sweet clover pasture, but was not needed by the pigs on soybean pasture.

Feeding Value, North Carolina.—Gray (1917), at the North Carolina Station, found that one lot of pigs on soybean pasture with no supplementary feed gained twice as rapidly for three months as another lot fed corn and shorts (2:1) in dry lot. In this test the soybeans produced 200 lb. of pork to the acre. At the central station 2.6 acres of soybeans with an average yield of 15 bu. to the acre furnished grazing without supplementary feed for 8 dry sows for 49 days during the fall after permanent Bermuda pastures were worthless, and the sows gained an average of 17 lb. each. Gray (1916) also conducted experiments to determine the relative values of peanuts and soybeans as grazing crops for pigs. With a half ration of corn, the soybeans afforded feed for 9 pigs for 61 days, but an equivalent area of peanuts afforded grazing only 36 days. The soybean fed hogs gained an average of 0.98 lb. per head daily at a cost of 5.2 cents per pound of gain. The peanut-fed hogs gained 1.36 lb. per head daily at a cost of 5.41 cents per pound of gain. Deducting the cost of grain the soybeans produced $18.80 and the peanuts $16.61 worth of pork per acre.

New Jersey Experiment.—At the New Jersey Experiment Station, Lewis and Clark (1913) found that soybeans would

produce a continuous supply of succulent green feed for chickens from August 15 until November, and that owing to their luxuriant growth they produced a liberal amount of shade for the birds. The soybean pods were not eaten.

Effects on the Fat of Swine.—Extensive investigations have been carried on by Gray (1916–1917) in North Carolina as to just what effect peanut pasturage, soybean pasturage and other feeds have upon the bodies of swine. Hogs that have been fed on peanuts and soybeans are discriminated against on the market, usually 1 to 2 cents a pound. In this work it was found that the melting point of lard from the kidney fat of hogs fattened on corn alone is approximately 43°C. A lot of hogs were grazed on soybean pasture supplemented with a partial ration of corn for 61 days, and the melting point of the leaf lard of two of the pigs averaged 37°C. The remaining pigs were finished for 41 days on corn alone, and the average melting point of the lard of these pigs was 39.8°C. The leaf fat of a few pigs fed in dry lot on corn and tankage (9:1) for 68 days had a melting point of 43.3°, while in some of the pigs fed this ration supplemented with soybean pasture for 60 days it was 33.3°C. The pigs remaining in the soybean lot were finished in dry lots for 21 days, when the lards taken from those finished on corn and tankage had a melting point of 35.6°C. and from those finished on corn and cottonseed meal, 38.5°C. The results of more recent work indicate that soft-bodied hogs can be brought back to normal in from 32 to 49 days when corn is fed in conjunction with cottonseed meal. So far, nothing else has been found equal, or even comparable, to cottonseed meal for hardening soft hogs.

Soybeans for Soiling.—The soybean has an important place among soiling crops. Having a high content of protein, the crop may be fed to good advantage with less nitrogenous crops such as corn, sorghum, and millet. The great variation in the dates of maturity of the numerous varieties or resulting from the planting of the same variety at different dates, makes it possible to have a succession of green forage throughout the summer and fall. When the crop has become well established, it grows well during drought and often succeeds where other crops fail. The palatability at different stages of development and ease of handling the crop also render the soybean a very valuable soiling crop.

Experimental Results.—At the Massachusetts Experiment Station, Goessmann (1891*a*) in a series of soiling experiments

with milch cows obtained results generally favorable both as regards yield and composition of milk from the summer feeding of green crops, particularly soybeans fed with brewers' grains.

At the Iowa Experiment Station Wilson, (1894) conducted a soiling experiment with milch cows. The following table gives data concerning the experiments and the results obtained. The results in general indicated the importance of feeding plants richer in protein than corn. The butter obtained by feeding soybean forage was of superior flavor and quality.

Table LXII.—Data and Results of Soiling Experiments with Milch Cows. Iowa Experiment Station

	Soiling crop			
	Peas and oats	Red clover	Sweet corn	Soy beans
Pounds fed daily to each cow	90	65	85	65
Pounds digestible protein daily	2.90	2.23	1.30	2.41
Crude protein, per cent	20.71	15.85	11.63	18.19
Milk, pounds daily	160	155	134	130
Fat, per cent	2.78	2.96	2.64	3.08
Fat, pounds daily	4.42	4.59	3.52	3.99
Flavor (perfect equal 45)	43	43	45	45

Soiling experiments were conducted with different forage crops at the Pennsylvania Experiment Station by Mairs (1911) for several years. In 1903 soybean forage was cut daily, except Saturday when sufficient was cut for 2 days. Five cows were fed 7 days at an average of 59 lb. per cow per day, showing that 1 acre would have supplied 2 cows for 12.5 days. The following table gives the dates of planting, periods

Table LXIII.—Soybean Soiling Experiment with Milch Cows. Pennsylvania Experiment Station

	1902	1903	1904	1905
Date of sowing	May 12	May 11	....	May 22
Period of harvesting	July 2 to Aug. 4	Aug. 8 to Aug. 19	....	July 29 to Aug. 7
Pounds fed daily per cow	58	59	....	40
Pounds green forage per acre	9,934	13,521	....	15,604
Pounds air dry forage per acre	2,016	2,995	2,505	3,238
Pounds protein per acre	270	355	317	427

of harvesting, the amount fed daily, and yields to the acre of soybean forage.

Soybeans for Ensilage.—The use of soybeans alone for ensilage is not to be recommended as shown by the results obtained by various experiment stations. Woll and Humphrey (1904) at the Wisconsin Experiment Station found that when soybean silage was used alone it was not readily eaten by the stock, the refuse amounting to about 10 per cent. Further, the silage had a rank, unpleasant odor and produced a bad effect in the quality of the milk, butter and cheese. At the Michigan Experiment Station, Smith (1905) noted a peculiar and unpleasant odor found in silage made from equal weights of soybeans and corn. Although the silage kept in good condition, was brown in color, and not badly fermented nor soft, a characteristic and unpleasant flavor was noted in the butter.

Extensive investigations have been made by Oakley and Westover with different kinds of silage. It was found by these investigators that soybean silage when tightly packed had no unpleasant odor. Moreover, the silage kept in good condition and was readily eaten by stock. Undoubtedly, if soybeans are ensiled alone and packed thoroughly, good silage would be obtained.

As an ensilage crop, however, in combination with corn, the soybean has been used to a considerable extent in the northern states. The silage, consisting of three parts corn and one part soybeans, keeps well, is readily eaten by stock, the animals show good gains in flesh and milk production, and no bad effects are produced in the quality of milk and its products. On account of the high protein content and rather low content of carbohydrates, soybeans alone tend to make strong smelling objectionable silage, while mixing with corn avoids the likelihood of strong odors, makes the silage more nutritious and not less palatable than from corn alone. The ensilage made from soybeans and corn has been found more digestible than that made from dent corn alone.

Corn in itself has a wide nutritive ratio and should be supplemented with feeds richer in protein to balance the ration.

Feeding Experiments.—At the Massachusetts Experiment Station one acre of soybeans produced 34 per cent. more protein than did one acre of flint corn cut green for fodder; while the acre of corn produced over 84 per cent. more of carbohydrates and fat than did the acre of soybeans. Lindsey (1893*a*) in feeding experiments with milch cows at this station found that a

mixed silage of equal parts of green corn fodder and green soybeans was equal to hay for milk production and much more economical.

At the Mississippi Experiment Station, Gayle and Lloyd (1917) in a feeding test with steers found 1 lb. of Goliad corn silage equivalent to 1.13 lb. of Goose-neck cane silage, or 0.9 lb. of equal parts mixture of Goliad corn and Early Amber sorghum silage, or 0.83 lb. of equal parts mixture of Goliad corn and Mammoth Yellow soybean silage.

In a feeding test by Alvord (1890) at the Maryland Experiment Station, two heifers were fed exclusively for 2 months on silage made from a mixture of corn, sorghum and soybeans. The results indicated that this silage was a good and sufficient feed for heifers, proving to be more than a maintenance ration. An experiment was conducted by Woods and Bartlett (1904) at the Maine Experiment Station with 6 cows, comparing soybean and corn ensilage with corn silage. The cows did practically as well on corn and soybean silage with 1 lb. less grain as on corn silage and grain.

Bergh (1920) at the Minnesota Experiment Station recommends a mixed ensilage of corn, sunflowers and soybeans. Cows fed on this cleaned up 40 lb. and more a day without showing a preference to any particular part of the mixture.

Analyses.—The following table gives analyses of soybean ensilage alone and in mixture, compared with corn silage.

TABLE LXIV.—ANALYSES OF SOYBEAN, SOYBEAN AND CORN, AND CORN SILAGES. COMPILED FROM VARIOUS SOURCES[1]

Kind of silage	Water, per cent.	Protein, per cent.	Carbohydrates, per cent.	Fat, per cent.	Ash, per cent.	Fiber, per cent.
Soybean	68.97	3.28	10.00	2.97	5.69	9.09
Soybean	74.20	4.10	7.00	2.20	2.80	9.70
Soybean	74.86	4.42	10.07	2.15	2.03	6.47
Soybean and corn	72.89	2.97	16.46	1.09	1.51	5.08
Soybean and corn	76.00	2.50	11.10	0.80	2.40	7.20
Soybean and corn	79.80	2.10	11.10	0.70	1.20	5.10
Soybean and millet	79.00	2.80	7.20	1.00	2.80	7.20
Corn	73.03	2.60	17.25	0.85	1.44	4.83
Corn	74.40	2.20	15.00	1.10	1.50	5.80

[1] No data were given as to the proportions of soybeans and corn in the silages. Varying proportions of the two crops no doubt account for the variations in the constituents.

Digestibility.—Experiments have been made by the Maine and Massachusetts Experiment Stations to ascertain the digestibility of soybean, and soybean and corn silage in comparison with corn silage. The following table shows the coefficients of digestibility as obtained from these experiments.

TABLE LXV.—DIGESTIBILITIES OF SOYBEAN AND OTHER SILAGES. COMPILED FROM VARIOUS SOURCES

Kind of silage	Animal	Organic matter, per cent.	Ash, per cent.	Protein, per cent.	Fiber, Per cent.	Nitrogenous free extract, per cent.	Fat, per cent.
Soybean	Goats	....	....	76.0	55.0	52.0	72.0
Soybean	Steers	....	....	55.0	43.0	61.0	49.0
Soybean and corn	Sheep	....	....	65.0	65.0	75.0	82.0
Soybean and corn	Sheep	73.2	42.7	62.6	65.1	79.1	67.7
Soybean and corn	Steers	72.2	31.3	56.4	61.7	80.5	66.7
Soybean and millet	Sheep	....	....	57.0	69.0	59.0	72.0
Corn	Sheep	77.0	32.5	65.4	77.4	78.5	82.9
Corn	Sheep	73.6	30.3	56.0	70.0	76.1	82.4

Soybean Hay.—The principal value of soybean hay lies in its high content of digestible protein. As indicated by comparative feeding tests it is equal to red clover, alfalfa or cowpeas for milk and butter production. Soybean hay makes an excellent winter ration for young cattle, sheep, and horses, and has been used to good advantage for hogs. The following table shows that the amount of digestible nutrients of soybean hay compares very favorably with the hay of other important crops. The relative value of feeds is, however, best indicated by comparative feeding tests.

TABLE LXVI.—DIGESTIBLE NUTRIENTS IN 100 LB. OF AIR-DRY SUBSTANCE[1]

Material	Total	Protein	Carbohydrates	Fat
Soybean	53.6	11.7	39.2	1.2
Cowpea	49.0	13.1	33.7	1.0
Alfalfa	51.6	10.6	39.0	0.9
Red clover	50.9	7.6	39.3	1.8
Timothy	48.5	3.0	42.8	1.2

[1] HENRY and MORRISON, Feeds and Feeding.

Feeding Tests.—At the Tennessee Experiment Station, Price (1908) conducted a feeding test comparing soybean hay and alfalfa hay in combination with corn ensilage and corn and cob meal. Each lot of cows consisted of 4 Jerseys and the test lasted through 3 periods of 30 days each. At the conclusion of the test, the results showed that the lot fed soybean hay produced 245 lb. of milk and 20.5 lb. of butter fat more than the lot receiving alfalfa hay.

In feeding tests at the Ohio Experiment Station, by Caldwell (1913) a ration of 8.7 lb. of soybean hay, 31.79 lb. of ensilage, 5.7 lb. of corn meal, and 1.0 lb. of cottonseed meal gave as good results as a ration of 8.4 lb. of concentrates (equal parts by weight of wheat bran, cottonseed meal, and corn meal) 7.0 lb. of corn stover and 32.8 lb. of ensilage. The feed cost of the butter fat produced was 9.5 per cent. lower in the soybean hay ration.

Soybean Straw.—The straw obtained from thrashing the soybean for seed is a valuable feed for all kinds of live stock. In

Fig. 38.—Thrashing soybeans from the field and baling the straw.

many sections where this crop is grown extensively for seed the straw is baled at the time of thrashing (Fig. 38) and sold in the immediate locality to liverymen, dairymen, and feeders. The straw also is of considerable value as fertilizer.

Feeding Value.—At the Ohio Experiment Station, Carmichael and Hammond (1912) conducted a series of experiments to compare corn stover and soybean straw for fattening lambs

when fed with shelled corn and linseed oilmeal. It was found that soybean straw produced 6.6 per cent. greater gain on a smaller amount of feed per 100 lb. of gain than did corn stover.

At the Tennessee Experiment Station, Price (1908) compared soybean straw and corn stover as roughages in the production of milk and butter. The ration containing soybean straw was found superior to that containing corn stover. This ration produced more pounds of milk and butter fat, and produced them more cheaply than the corn stover ration. In every case there was less loss in milk and butter fat during the feeding of soybean straw than during the feeding of corn stover. During the last period of feeding, one lot of cows, on soybean straw, actually gained 57 lb. of milk over the preceding period on corn stover. It was concluded from these tests that soybean straw is a valuable roughage in the feeding of dairy cows.

The following table gives the digestive nutrients of soybean straw as compared with those of other roughages.

Table LXVII.—Digestible Nutrients in 100 Lb. of Soybean Straw and in Other Roughages[1]

Roughage	Protein, lb.	Carbohydrates, lb.	Fat, lb.	Total, lb.
Soybean straw	2.8	38.5	1.0	43.5
Cowpea straw	3.4	39.1	0.7	44.1
Crimson clover straw	3.8	36.5	0.9	42.3
Bean straw	3.6	42.4	0.7	47.6
Wheat straw	0.7	35.1	0.5	36.9
Oat straw	1.0	42.6	0.9	44.6
Corn fodder	1.0	12.8	0.4	14.7

Fertilizer Value.—Although soybean straw is more generally used for feeding, in some cases it is used for spreading on the land for its fertilizing value. The more economical plan would be to feed the straw and apply the manure to the soil. The following table gives the fertilizing constituents of soybean straw.

[1] Henry and Morrison, Feeds and Feeding.

TABLE LXVIII.—FERTILIZING CONSTITUENTS OF SOYBEAN STRAW COMPARED WITH THOSE OF WHEAT, OATS, BARLEY, AND RYE[1]

Straw	Fertilizing constituents in 1,000 lb.		
	Nitrogen	Phosphoric acid	Potash
Soybean	9.0	1.2	8.9
Wheat	5.0	1.3	7.4
Oats	5.8	2.1	15.0
Barley	5.6	1.8	12.0
Rye	4.8	2.8	7.9

When special harvesters are used for gathering seed, the vines are left standing and later are turned under. Analyses of plants from which seed have been gathered by these harvesters indicated one ton of this straw to contain 10.1 lb. of nitrogen, 2.1 lb. of phosphoric acid, and 17.6 lb. of potash.

[1] HENRY and MORRISON, Feeds and Feeding.

CHAPTER IX

VARIETIES

The varieties of soybeans are very numerous, upwards of 800 having been tested by the United States Department of Agriculture. New sorts are secured from Oriental countries and by breeding, which differ widely in agricultural value. Although yield is the most important single desideratum, other considerations are important, such as habit, coarseness, color of seed, ability to hold leaves, ease of shattering, and length of season required to mature. In view of the increasing importance of the soybean for the production of oil, the percentage of oil content is second in importance to yield for seed production alone.

At the present time about twenty varieties of soybeans are handled by seedsmen and growers in the United States. During the past 10 years more than seven hundred varieties have been introduced from China, Manchuria, Japan, and India. From among these several have since become established in American agriculture. Others of more recent introduction have proven so valuable in trials that they are deemed important acquisitions and doubtless will become widely grown.

Unfortunately, considerable confusion in the names of varieties has been caused by seedsmen and growers, the same variety being frequently known under several different names. With the introduction of more varieties greater confusion may easily occur unless every precaution be exercised.

Among the many varieties introduced from China and Manchuria it is a very interesting fact that the same variety has rarely been secured a second time unless from the same place. It appears that practically every locality in these countries has its own local varieties. In general, the earliest varieties come from the northernmost localities, the latest from the southernmost.

Japanese Classification of Varieties.—In Japan varieties of soybeans are distinguished largely according to the color, shape and size of seed, period of maturity; also according to

use, as those which serve principally in making shoyu, tofu, miso, and those used for ordinary purposes.

(*A*) The white (pale yellow) called in Japanese *Shiro-mame* or *Hakudaidzu*, includes the following important varieties:

Goguwatsu-mame (five-months kind) also called *Tofu-mame*, because it is used chiefly in making tofu, is an early ripening sort with very small seeds.

Wase-mame is another small-seeded early-ripening variety used in making tofu, and is also termed *Tofu-mame.*

Nakate-mame (middle late bean) matures between the early and late varieties and has round seeds somewhat larger than the above early sorts.

Okute-mame, Maru-mame, and *Teppo-mame,* or *Aki-mame* are late maturing varieties with round seeds which become harder and longer than the early ones. The *Teppo-mame* is used largely in making shoyu, while *Maru-mame* is valuable as horse feed.

(*B*) The black varieties, Japanese *Kuro-mame* or *Kodu-daidzu,* are for the most part eaten boiled, with sugar, as a relish to rice. *Kuro-mame* is a middle-late variety with round or ellipsoid seeds and is somewhat similar to *Kuro-teppo-mame* which has large round seeds. There is also a late maturing sort with flat ellipsoid seeds known under several names.

(*C*) The brown-seeded varieties, Japanese *Katsu-daidsu,* are much less grown than the white and black sorts, and are used like the latter. Varieties with reddish-brown, round seeds are called *Aka-mame,* while three light-brown sorts of small importance are termed *Cha-mame* (tea beans).

(*D*) Greenish or bluish-green varieties, Japanese *Aö-mame* or *Seidaidzu* are mostly boiled with sugar like the brown and black varieties. Similar to the brown sorts, they are much less widely grown than the black and white varieties. The Japanese distinguish the following sub-varieties:

1. *Sei-hito.* Epidermis green with yellow germ.
2. *Nikuri-sei.* Epidermis green with green germ.

   Both of these sorts range from round-ellipsoidal to a bullet roundness and are of medium size.

3. *Kage-mame.* Epidermis pale green, round with yellow germ.

(*E*) The speckled or bicolored varieties. Japanese *Fuiri-mame* or *Han-daidzu,* is a group of small importance and their cultivation is confined to a small area in a few provinces. The following sub-varieties are recognized:

1. *Kuro-kura-kake-mame.* Seed greenish, flat, ellipsoid with a black spot on the scar.
2. *Aka-kura-kake-mame.* Seed yellowish green, flat, long with a brown spot on the scar.
3. *Fuiri-mame or Udzura-mame.* Seed yellowish-green, spotted with many dark flecks. This is a rare variety grown only in a few localities.

Classification of Varieties in Manchuria.—In Manchuria three main groups of soybeans are distinguished according to color of seed, this number being found adequate for commercial purposes and use among the Chinese. These three divisions are:

(*A*) Yellow.

1. *Pai-mei* or white eyebrow, from the whiteness of the hilum or seed scar.
2. *Chin-huän* or round golden bean.
3. *Hei-chi* or black navel, from the dark brown hilum. In this sub-variety the color and size of the hilum are said to vary considerably.

(*B*) Green (*Ching tou*).

1. Epidermis green; germ yellow.
2. Epidermis green; germ green.

(*C*) Black (*Wu tou*).

1. *Ta wu tou* or large black; germ green.
2. Small black; germ yellow.
3. *Pieu wu tou* or flat black; germ yellow.

There is a great number of sub-varieties of these groups each differentiated by some small characteristic.

These oriental classifications are of little value as most of the names apply to two or more agronomically distinct varieties.

Botanical Classifications.—The numerous varieties of soybeans have led some botanists to give them botanical designations, but these for the most part have been ignored by later writers.

Roxburgh (1832) described a variety in the Calcutta Botanical Garden as *Soja hispida pallida*, stating that it had yellow flowers and white seeds. Voigt (Hortus Suburbanus Calcuttensis, p. 231) apparently redescribes the same plant as *Soja hispida leucosperma*. There is perhaps an error here as all of the varieties of soybeans grown by us have either white or purple flowers and none have truly white seeds.

Martens (1869) discusses the soybean under the name *Soja*

hispida Moench and gives a classification of thirteen varieties that he had secured from various sources, of which he apparently grew but one. He divides the species into three sub-species based on the form of the seed, under which the varieties are named according to the color of the seed.

I. *Soja elliptica* Martens. Seeds oval.

1. *S. elliptica nigra.* Seeds black; obtained from Shanghai and Paris.
2. *S. elliptica castanea.* Seeds brown; obtained from Chefoo, Venice and Berlin.
3. *S. elliptica virescens.* Seeds greenish yellow; obtained from Paris.
4. *S. elliptica lutescens.* Seeds yellow; obtained from Chefoo.

II. *Soja sphærica.* Seeds globose.

5. *S. sphærica nigra.* Seeds black, large; obtained from Japan.
6. *S. sphærica minor.* Seeds black, small; obtained from Japan and Sumatra.
7. *S. sphærica virescens.* Seeds greenish; obtained from Shanghai and Yokohoma.
8. *S. sphærica lutescens.* Seeds yellow, large; obtained as "New Japan peas" from Norway. This is identified as var. *pallida* of Roxburgh.
9. *S. sphærica minima.* Seeds yellow, small; obtained from Yokohoma.

III. *Soja compressa.* Seeds compressed.

10. *S. compressa nigra.* Seeds black, very large; obtained from Yokohama.
11. *S. compressa parvula.* Seeds black, small, obtained from Chefoo.
12. *S. compressa virescens.* Seeds greenish; obtained from Berlin as *Soja ochroleuca* Bouche.
13. *S. compressa zebrina.* Seeds brown banded with black; obtained from the Berlin Botanic Garden.

Harz (1880–1885) gives an even more elaborate classification than Martens of the varieties of *Soja hispida*, dividing the species into two subspecies on the form of the pod, and numerous varieties on the shape and color of the seeds, but it is not apparent that he grew the plants. His grouping is as follows:

Soja platycarpa Harz. Flat-podded soybeans.

1. *olivacea* Harz. Seeds olive-brown.
2. *punctata* Harz. Seeds olive, speckled with brown.
3. *melanosperma* Harz. Seeds black, elongate (*Soja compressa nigra* Martens).
   (*a*) *vulgaris*. Hilum flat; seeds 9.1 × 5.5 × 3.5 mm.
   (*b*) *renisperma*. Hilum concave; seeds 10.1 × 5 × 3.8–4 mm.
   (*c*) *nigra*. (*Sojo elliptica nigra* Martens). Seeds little compressed, 11 × 5.1 × 4.4 mm.
   (*d*) *rubrocincta*. Like the preceding, but dark red about the hilum.
4. *platysperma* Harz. Seeds black, flat.
5. *parvula* Martens. Seeds black, small.

Soja tumida Harz. Swollen-podded soybeans.

6. *pallida* Roxb. Seeds yellow or yellowish.
7. *castanea* (*Soja elliptica castanea* Martens). Seeds brown.
8. *atrosperma* Harz. (*Soja sphærica nigra* and *S. sphærica minor* Martens). Seeds black.

This classification differs from that of Martens primarily in recognizing two main groups based on the shape of the pod rather than three groups based on the form of the seed.

While either the system of Martens or that of Harz will classify the material, they are of little value either botanically or agronomically. To accommodate the much larger number of varieties now known, either scheme would need to be elaborated greatly. Furthermore, there are all possible intergrades between flat pods and tumid pods, as also between ovoid, globose and compressed seeds. Botanically speaking, the form of the pod and the color and form of the seeds is of little significance. Agronomically, the habit and size of the plants are much more important characters, and in many cases varieties very different in these respects have closely similar seeds.

VARIETAL CHARACTERISTICS

Habit of Growth.—All soybeans are strictly determinate as to growth; that is, the plants reach a definite size according to environment and then mature and die. The great majority of varieties are erect and branching with a well-defined main stem. The branches may be short, or the lower ones elongated, either spreading or ascending. In other varieties the stems and branches, especially the elongated terminals, are more or less

twining, and usually weak, so that the plant is only suberect or even procumbent. In the bushy forms the internodes may be short, in which case the pods are more or less densely crowded; or elongated, when the pods are scattered. Varieties with elongated internodes are usually slender and the pods small, but this is by no means universal. The form of the plant may be greatly modified by thickness of planting, as the development of the branches is inhibited by close planting and encouraged by isolation.

Foliage.—A wide variation occurs in the leaves of soybeans, involving shape, size, color, and degree of persistence. These

Fig. 39.—The larger plant is the Guelph or Medium Green which is very pubescent, while the smaller plant is a nearly smooth variety from Japan.

characters merge by insensible degrees, so that they are useful in differentiating varieties only in extreme cases. In shape, the leaflets are usually ovate-lanceolate, but in some varieties are narrowly lanceolate or almost linear as in the Shingto; in others

nearly orbicular. They vary in length from 1 in. to 5 in. In color they are usually a pale green, but some are dark green.

In nearly all varieties of soybeans the leaves commence to turn yellow as the pods begin to ripen and commonly all have fallen when the pods are mature. On this account it is difficult to harvest the crop for grain and save all the foliage as well, but this is possible with several varieties. A few sorts, like the Wisconsin Black, retain their leaves green until all or nearly all of the pods are mature.

Additional leaflets occur not uncommonly in several varieties. This seems to be especially true with early sorts from Siberia, on which leaves with four or five leaflets are frequent.

Pubescence.—All soybeans are hairy plants, and there is but little difference in the amount of hairiness. No smooth variety has thus far been obtained, the nearest approach to it being a variety (Fig. 39) obtained from Tokio, Japan. There are said to be several smooth varieties in Japan, but all so far introduced into the United States are somewhat hairy. The pubescence occurs in two colors, white or gray and tawny, which behave in Mendelian fashion, the tawny being dominant. The tawny pubescence is nearly always on tawny-colored or dark pods and the white pubescence on grayish or straw-colored pods. Many cases occur where two varieties differ wholly or mainly in the color of the pubescence. In some instances these have been segregated; in others the mixture is evident. In such cases one color usually predominates, the presence of the other being due to casual hybridization. In a study of differences of amount of pubescence in American varieties and those of India, Woodhouse and Taylor (1913) note that in the Bengal types I–V the leaves differ from the American varieties and Nepali (type VI) in being covered with soft, upright hairs on their upper surfaces, whereas the upper surfaces of the latter types are covered with closely appressed hairs. The American varieties and Nepali type can be distinguished at a distance from the fully pubescent types by the darker green color of their leaves.

Flowers.—The flowers are borne on short axillary or terminal racemes, commonly with 8 to 16 in each cluster. In some varieties, however, the racemes may have as many as 35 or more flowers. Most soybean flowers have no perceptible odor; but three varieties when in full flower at Jackson, Tenn., 1909, were very fragrant, the odor suggesting that of lilacs.

FIG. 40.—Pods of soybeans showing the range in size and shape. (Natural size.)

Soybean flowers occur in two colors, purple and white. Certain varieties can be distinguished most readily by this character.

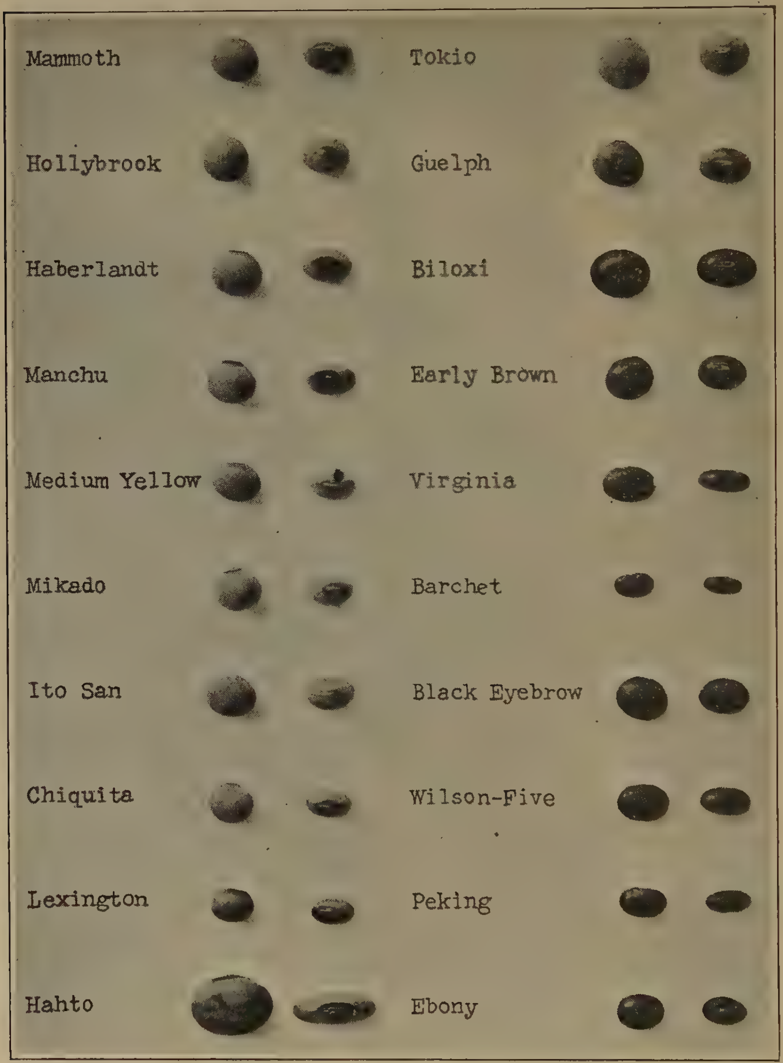

Fig. 41.—Seeds of the most important varieties of soybeans now grown in the United States showing wide range in size and shape of seed.

In a large number of cases both colors of flowers occur, the plants otherwise resembling each other closely. The two strains differing wholly or mainly in flower color can, however, be readily

separated. Roxburgh (1832) and Voigt each describe a variety with white seeds and yellow flowers. There is perhaps an error here as there is no hint of yellow flowers in the 800 or more introductions studied by the U. S. Department of Agriculture.

Pods.—In most varieties of soybeans the pods are distinctly compressed, but in some cases cylindric, and all possible intermediate forms exist (Fig. 40). The number of seeds to the pod in most varieties is 2 to 3. In a few sorts, however, the number is 3 to 4. Wein (1879) speaks of varieties having occasionally 4 to 5 seeds in a pod, but in our extensive studies of varieties we have never seen but one example of a 5-seeded pod. The largest pods measure from 3 to 3½ in. long and the smallest from 1 to 1½ in. long.

Soybean pods are commonly borne in clusters of 3 to 5 In some varieties the clusters may contain as many as 8 to 15 pods. Depending on the length of the internodes, the pods appear crowded or scattered. A single plant may bear over 400 pods. The color of the pods may be gray, straw yellow, tawny, or black. Gray pods bear white or grayish hairs while tawny pods have tawny pubescence. Nearly all black pods bear white or grayish hairs.

Under changeable weather conditions most soybean varieties tend to shatter their seeds easily. Among the varieties tested at Arlington Farm, Virginia, some varieties were noted to hold seeds better than others. The Biloxi variety has been found an excellent sort on account of holding its seeds better than other varieties commonly grown in the southern states. Thus far only one variety, S.P.I. No. 22876 from Japan, has shown a non-shattering character. Hybrids between this variety and easily shattering sorts show the character to be transmitted.

Size and Weight of Seeds.—The range in size and shape of soybean seeds according to variety is well shown in Fig. 41. None is truly globose, but this shape is closely approximated by some varieties. Others are much compressed. The great majority, however, are elliptic in outline, the thickness less than the breadth.

The size and weight of the seeds vary considerably, the lowest weight per hundred seeds being 4.3 grams and the highest 21.2 grams. Soybean seeds weigh about 60 lb. to the bushel and this weight is recognized as standard throughout the United States. In Manchuria the weight per bushel is usually 40 lb. The follow-

ing table shows the number of seed to the bushel and weight in grams of 100 seeds of the important commercial varieties.

TABLE LXIX.—NUMBER OF SEEDS PER BUSHEL AND WEIGHT IN GRAMS OF 100 SEEDS OF THE MOST IMPORTANT VARIETIES

Variety	Number of seed per bu.	Weight in grams of 100 seeds	Variety	Number of seed per bu.	Weight in grams of 100 seeds
Mammoth	132,480	21.2	Early Brown	170,000	
Hollybrook	175,680	17.3	Virginia	249,600	11.6
Haberlandt	141,120	20.4	Jet	340,000	
Manchu	140,160	20.0	Barchet	644,160	4.3
Ito San	171,840	15.7	Black Eyebrow	147,840	19.1
Midwest	261,120	10.6	Shanghai	164,000	
Chiquita	274,560	10.4	Arlington	306,240	9.0
Tokio	142,080	19.3	Peking	348,480	7.8
Guelph	148,800	19.0	Wilson-Five	327,360	9.8
Biloxi	112,000	....	Ebony	345,000	
Hahto	75,000	....	Lexington	215,000	

Color of Seeds.—Most varieties of soybeans have unicolored seeds in the following colors: Straw yellow, olive yellow, green, olive, brown, and black, the last really a dark violet. Straw-yellow seeds are in some varieties very pale, especially when old, and are sometimes erroneously called white, but no truly white seeds are known in soybeans. In several varieties, like the Mammoth, the seeds have a greenish tinge if harvested before maturity, making it difficult to distinguish them from varieties whose fully mature seeds are greenish-yellow. The latter again merge by very fine gradations into olive and from this into brown. Bi-colored seed occurs in but few varieties. The commonest are green or yellow with a saddle of black, the latter not sharply delimited. Some varieties have their seeds brindled brown and black, the two colors somewhat concentrically arranged. One variety has black seeds faintly marked with minute brown specks. On heterozygote plants the seeds are often irregularly bicolored and in some cases tricolored. Among recent introductions from Chosen (Korea) were several black and a few brown varieties with the outer layer of the testa broken by numerous cracks so as to expose the inner white layer (Fig. 42). In the case of the black sorts this splitting has a net-like appearance, giving the beans a black and white color.

The hilum or seed scar may be of the same color as the seed coat as in the case of black, brown, and a few yellow seeded varie-

ties or it may range from a pale brown to black in most straw-yellow, olive-yellow, and green seeded sorts. In the latter case the color of hilum is often of value in distinguishing varieties having the same outer color. In a few varieties, as in Ito San, there is a minute brown spot on the micropyle which is diagnostic.

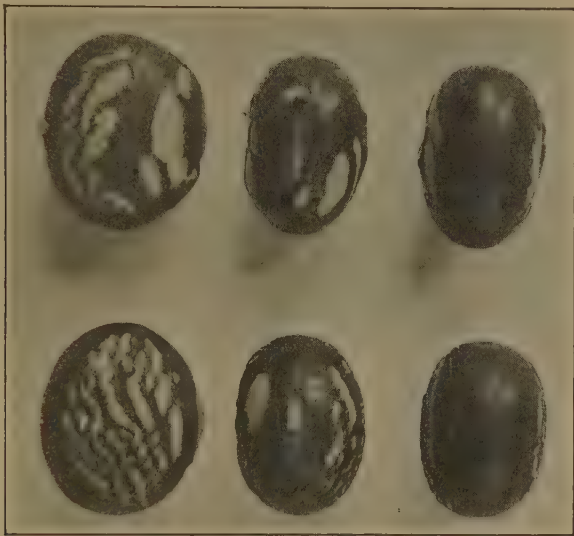

FIG. 42.—Seeds of a black and white variety (Widower) from Korea. The white is due to the splitting of the outer layer of the testa.

Frost Resistance.—Soybeans will withstand considerable frost, both in the spring, when young, and in the fall, when about mature. The trials at the Arlington Experimental Farm, near Washington, D. C., indicate that varieties vary to a considerable degree in this respect. The first frost in the fall of 1909 at this farm came on October 13, the minimum temperature being 31°F. The top leaves of nearly all varieties were slightly touched by frost. The varieties from India were injured to a greater extent than any of those previously grown. The first killing frost occurred on October 29, 1909, the minimum temperature being 27°F. In the majority of the late and very late varieties the plants were killed. However, several varieties still retained a fair percentage of green leaves, and the pods were but slightly touched. The Riceland and Barchet varieties showed consider-

able frost resistance, about 50 per cent. of the leaves and all the pods remaining green after this later frost. The most resistant variety in the trial was No. 20798-E, a selection from No. 20798, Barchet, this variety still having about 70 per cent. of its leaves green and no pods injured. Those varieties showing any degree of resistance still retained green leaves and pods on November 15, the temperature meantime not reaching the minimum of October 29.

In a variety trial at Muskegon, Mich., in 1909, the Guelph, Ito San, and Ogemaw varieties were found to be quite frost resistant and the Chernie, Jet, and Meyer extremely sensitive. The comparative resistance of varieties is reported as follows, the first being least injured: (1) Ogemaw; (2) Haberlandt, Ito San, Kingston, Guelph; (3) Habaro, Shingto, Manhattan, Brindle; (4) Jet; (5) Meyer, Chernie.

It may be that the same variety varies in frost resistance, depending on its stage of maturity. In the foregoing list, however, the Ogemaw, though very early, usually matures with the Manhattan and the Chernie, while the Haberlandt is 15 days later.

Period to Maturity.—In soybeans there is a complete series of varieties from very early to very late. With very few exceptions, earliness is correlated with size, the tallest varie-

Table LXX.—Results of Planting a Single Variety of Soybean at Different Dates. Vienna, Austria, 1877.

Date of planting	Date of harvest	Life period, days	Total heat required		
			Until germination, deg. C.	Until blossoming, deg. C.	Until maturity, deg. C.
March 31	September 29	182	230	1,185	2,972
April 7	September 29	175	294	1,102	2,893
April 14	September 29	167	189	1,008	2,787
April 21	September 29	160	217	1,026	2,753
April 28	September 29	153	228	995	2,701
May 5	October 15	163	209	936	2,811
May 12	October 15	156	221	960	2,722
May 19	October 18	152	275	1,043	2,641
May 26	October 18	145	153	985	2,519
June 2	October 18	138	152	871	2,405
June 9	October 26	139	130	739	2,322

ties being latest. As in the cowpea, early plantings take a longer time to mature than late plantings, but there is by no means a consistent behavior in the different varieties in this respect. In general, the later the variety the more is its life period shortened by later planting. See Table LXXIV.

Haberlandt (1877) planted one variety at Vienna at intervals of one week through the season and attempted to correlate the life periods obtained with the amount of heat. His results are shown in Table LXX.

Prof. C. A. Mooers (1908) has conducted extensive experiments of a similar kind. The following table gives some of his results:

TABLE LXXI.—RESULTS OF PLANTING DIFFERENT VARIETIES OF SOYBEANS AT DIFFERENT DATES AT KNOXVILLE, TENN.[1]

Variety	1907			1908		
	Date planted	Date harvested	Life period, days	Date planted	Date harvested	Life period, days
Mammoth........	April 3	October 5	186	April 2	October 2	188
	April 15	October 5	173	April 14	October 2	179
	April 30	October 6	160	May 1	October 2	159
	May 15	October 9	146	May 15	October 2	145
	June 5	October 19	129	June 1	October 2	128
	June 17	October 22	127	June 17	October 21	126
	June 29	October 22	113	July 1	October 21	112
	July 15	October 28	105	July 16	October 24	100
	April 3	September 13	164	April 2	August 15	135
Midwest.........	April 15	September 13	151	April 14	September 7	146
	April 30	September 13	137	May 1	September 14	136
	May 15	September 18	135	May 15	September 14	122
	June 5	September 20	107	June 1	September 19	110
	June 17	September 27	102	June 17	September 23	98
	June 29	September 27	90	July 1	September 28	89
	July 15	October 9	86	July 16	October 17	93
	August 6	October 29	84	August 1	October 24	85
Ito San..........	April 3	August 9	129	April 2	July 25	114
	April 15	August 9	117	April 14	July 29	106
	April 30	August 9	102	May 1	August 5	96
	May 15	August 17	93	May 15	August 15	92
	June 5	September 3	90	June 1	August 27	87
	June 17	September 18	93	June 17	September 10	85
	June 29	September 18	81	July 1	September 19	80
	July 15	October 9	85	July 16	October 6	82
	August 6	October 29	84	August 1	October 24	85

[1] Tenn. Agri. Exp. Sta. Bull. 82, December, 1908.

A large list of varieties has been grown for several years past at the Arlington Experimental Farm, Virginia, planted each year about the first of June. In period of maturity nearly all of the varieties behave consistently from season to season, as indicated in the following table.

Table LXXII.—Life Period of Soybean Varieties Grown at the Arlington Experimental Farm, Va., for Eight Seasons

Variety	Life period (days)							
	1905	1907	1908	1909	1910	1911	1912	1913
No. 17251, Buckshot	103	103	99	100	103	107	98	
No. 17252, Flat King	128	132	128	136	146	131	131	
No. 17253, Nuttall	114	117	121	119	118			
No. 17254, Ebony	122	123	121	124	121	120	122	116
No. 17255, Kingston	114	117	118	124	121			
No. 17256, Brownie	121	124	121	124	121			
No. 17257, Eda	112	117	114	112	111			
No. 17258, Ogemaw	88	102	105	112	111	...	104	
No. 17260, Samarow	103	102	105	112	111	108	110	
No. 17261, Guelph	112	117	118	117	116	122	115	116
No. 17262, Yosho	103	107	104	109	111			
No. 17263, Austin	119	127	123	136	134	142	123	127
No. 17264, Tokyo	149	137	134	150	146	...	145	149
No. 17267, Hope	149	138	134	149	146	150	145	149
No. 17268, Ito San	113	117	106	117	111	...	98	99
No. 17269, Midwest	121	124	123	124	122	124	119	116
No. 17271, Haberlandt	119	...	119	129	122	124	131	121
No. 17273, Butterball	96	117	105	112	111	116	116	
No. 17275, Amherst	114	122	119	124	122	115	119	116
No. 17277, Manhattan	96	117	98	105	93	...	106	
No. 17278, Hollybrook	133	137	128	138	131	...	128	135
No. 17280, Mammoth	147	142	146	150	150	152	152	
No. 17861, Jet	...	117	124	129	122	130	131	118
No. 18227, Chernie	...	117	112	105	103	...	106	107

Disease Resistance.—Investigations have been carried on by United States Department of Agriculture concerning the resistance of soybean varieties to diseases, especially wilt and nematode. Out of a very large series of varieties tested on the soils of South Carolina, Georgia, and Florida where wilt and nematode are prevalent, the Laredo and three unnamed varieties showed high resistance to these diseases.

Cromwell (1917), in investigations on the susceptibility of different varieties of soybeans to Fusarium in North Carolina found that the Black Eyebrow variety showed resistance. The Mammoth Brown variety, while not resistant, appeared tolerant and developed remarkably in spite of numerous fungus filaments and nematodes within the roots. Fifteen other varieties tested were found to be severely affected.

Woodworth and Brown (1920) in studies on varietal resistance and susceptibility to bacterial blight of soybeans at the Wisconsin Experiment Station found that soybean varieties vary greatly in their relative susceptibility to the bacterial blight. Of forty-seven varieties grown in 1918, about one-half were completely resistant while the others ranged from complete susceptibility to partial resistance.

Considerable bacterial blight was noted in the 1921 soybean variety tests at Arlington Farm, Virginia, which included about three hundred varieties. The varieties ranged from complete resistance to complete susceptibility. The Midwest variety of which there were numerous samples from various sources was completely susceptible in every instance.

Classification by Lengths of Life Period.—Based on the data from variety tests at the Arlington Experimental Farm, the varieties may be classified into seven groups according to their life periods:

Very early	Maturing in 80 to 90 days,
Early	Maturing in 90 to 100 days,
Medium early	Maturing in 100 to 110 days,
Medium	Maturing in 110 to 120 days,
Medium late	Maturing in 120 to 130 days,
Late	Maturing in 130 to 150 days,
Very late	Maturing in more than 150 days.

Observations made by Woodhouse and Taylor (1913) at Sabour, India, show that newly imported American varieties take a considerably shorter time to mature at Sabour than in America, but that plants from acclimatized seed mature somewhat later than those from freshly imported seeds. A statement of their observations is given in Table LXXIII.

Table LXXIII.—Life Periods of American Varieties of Soybeans Grown at Sabour, India, 1911

Variety	Origin	Date of planting	Date of harvesting	Life period at Sabour, days	Life period in United States, days
Barchet	S.P.I. No. 23232	July 12	October 18–28	99–108	More than 150
Barchet	Acclimatized from Saharanpur	July 12	November 9–17	120–128	More than 150
Duggar	S.P.I. No. 17268C	July 12	October 11	91	110–120
Haberlandt	S.P.I. No. 17271	July 12	October 31	111	120–130
Hollybrook	S.P.I. No. 17278	July 12	October 19	99	130–150
Mammoth	S.P.I. No. 30205	July 12	October 25	105	130–150
Peking	S.P.I. No. 17852B	July 12	September 30	80	120–130
Pingsu	S.P.I. No. 18259	July 12	September 25	75	120–130
Riceland	Acclimatized from Saharanpur	July 12	November 13	124	More than 150

Desirable Characters in Varieties.—The determination of the best variety for any locality will depend first on whether it is grown primarily for hay or for grain, or for both purposes. In this, as with other crops, yield is the most valuable single desideratum. Secondary considerations of importance are habit of plant, degree of coarseness, ability to retain the foliage, color of seed, ease of shattering, and percentage of oil.

Erectness of stem with upright or ascending branches is a prime requisite of a desirable variety. A tall habit is also important, as dwarf varieties usually bear pods very close to the ground, so that many will be left in the stubble, which is not the case in most tall sorts.

An objection to some varieties is the coarse, woody stems which make mowing difficult. There are many slender varieties where this objection does not hold, but slenderness is usually accompanied with small pods and seeds, and often with vining tips and a tendency to lodge. Unless there is lodging, such varieties are easily mown.

Nearly all varieties begin to shed their leaves as the pods ripen. There are a number of exceptions to this, like the Wisconsin Black when the leaves remain green even after all the pods are mature. It may be possible to combine this character as a valuable feature to later varieties to be grown both for hay and grain.

TABLE LXXIV.—LIFE PERIOD OF SOYBEAN VARIETIES PLANTED AT INTERVALS OF TWO WEEKS IN 1911 AT THE ARLINGTON EXPERIMENTAL FARM, VIRGINIA

Date of planting	Days to bloom				Life period, days				Number of pods per plant			
	Ogemaw	Auburn	Haber-landt	Mam-moth	Ogemaw	Auburn	Haber-landt	Mam-moth	Ogemaw	Auburn	Haber-landt	Mam-moth
May 1	40	45	61	66	102	143	144	186	35	108	160	165
May 15	35	42	54	56	93	128	130	173	35	140	156	150
June 1	38	43	50	62	87	117	124	157	20	120	155	152
June 15	32	40	45	55	86	109	119	142	20	85	125	140
July 1	27	34	44	53	85	107	116	133	30	90	120	105
July 15	28	33	41	44	87	104	112	123	30	60	50	51
August 1	31	35	39	43	85	99	...	...	12	22	45	31
August 15	34	36	39	41	...	...	...	...	6	15	15	17

The color of seed is a matter of some importance, depending upon the purpose for which the crop is grown. The yellow-seeded varieties are the most suitable for the production of oil and meal as they contain the highest percentage of oil and produce a better-appearing meal or flour. Yellow or green seeds are also preferable to darker colors for pasture, as the shattered seeds are more easily found by hogs in field or stubble.

When grown for grain alone, shattering of the pods is a serious fault. Some varieties, like the Guelph, shatter inordinately; others, like Biloxi, shatter scarcely at all; while most varieties shatter somewhat, especially during changeable weather if not harvested when ripe. As a rule the varieties with large pods and seeds shatter much worse than those with small pods and seeds. In a few varieties, like Brownie, the seed coats break badly in thrashing, a very objectionable character.

In sections where nematodes and cowpea wilt occur most soybean varieties are seriously affected by both these diseases. A few varieties like Laredo, however, exhibit considerable resistance to these diseases, and there is good ground to believe that practically immune strains can be developed.

Descriptions of Important Varieties.—Forty-three varieties of soybeans that have been found agriculturally the most valuable under American conditions up to 1922 are here described. These have been selected as the best of over 800 varieties introduced by the United States Department of Agriculture and thoroughly tested in the different parts of the United States. It will be noted in the data given for the varieties that most of them are introductions, but a few are "selections" which may have been incidental mixtures but more likely natural hybrids. "S.P.I." signifies Seed & Plant Introduction, each lot introduced by the United States Department of Agriculture being designated by a special number to facilitate easy recording.

A.K.—Introduced from Manchuria, about 1912. Plants stout, erect, bushy, maturing in about 110 days; pubescence, tawny and gray; flowers purple, 50 to 55 days to flower; pods 35 to 45 mm. long, 8 to 9 mm. wide, 6 to 7 mm. thick; number of seeds, 2–3; seed straw yellow, 7 to 8 mm. long, 6 to 7 mm. wide, 5 to 6 mm. thick; hilum light brown; germ yellow; oil 19.2 per cent.; 159,000 to bushel.

Aksarben.—Introduced from Fakumen, Manchuria, 1913. Plants stout, erect, maturing in about 110 days; pubescence

gray; flowers purple, 40 to 45 days to flower; pods straw, 40 to 45 mm. long, 9 to 11 mm. wide, 6 to 8 mm. thick; 2 to 3, seeds straw yellow, 7 to 8 mm. long, 6 to 8 mm. wide, 5 to 6 mm. thick; hilum pale; germ yellow; oil 19.0 per cent.; 161,000 to the bushel.

Barchet.—Introduced from Shanghai, China, 1908. Plants slender, rather inclined to lodge on rich soils, maturing in about 160 days; pubescence tawny; flowers purple, 80 to 85 days to flower; pods tawny, 30 to 35 mm. long, 4 to 5 mm. wide, 3 to 4 mm. thick; number of seeds 2–3; seed brown, 6 to 7 mm. long, 3 to 4 mm. wide, 2 to 3 mm. thick; hilum brown; germ yellow; oil 13.3 per cent.; 645,000 to bushel.

Biloxi.—Introduced from Tangsi, China, 1908 (Fig. 43). Plants stout, erect, bushy, maturing in about 165 days; pubes-

Fig. 43.—A field of the Biloxi soybean, which requires a long season to mature.

cence tawny, flowers purple, 85 to 90 days to flower; pods 60 to 65 mm. long, 8 to 10 mm. wide, 8 to 9 mm. thick; number of seeds, 2–3, dark-brown, 10 to 11 mm. long, 7 to 8 mm. wide, 6 to 7 mm. thick; hilum brown; germ yellow; oil, per cent. 20.1; 112,000 to bushel.

Black Beauty.—The same as Ebony.

Black Eyebrow.—Introduced from Wulukai, Manchuria, 1911. Plants stout, erect, maturing in about 110 days; pubescence tawny; flowers both purple and white, 35 to 40 days to flower; pods tawny, 35 to 45 mm. long, 8 to 9 mm. wide, 5 to 6 mm. thick, 2–3 seeded; seeded black with brown saddle, 7 to 8 mm. long, 6 to 7 mm. wide, 4 to 5 mm. thick; hilum black; germ yellow; oil 19.9 per cent.; about 148,000 to bushel.

Chestnut.—Selection from Habaro in 1907. Plants stout, erect, maturing in about 105 days; pubescence tawny; flowers purple, 40 to 45 days to flower; pods brown, 35 to 50 mm. long, 8 to 9 mm. wide, 6 to 7 mm. thick, 2–3 seeded; seeded russet, 7 to 8 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick; hilum russet; germ yellow; oil 18.3 per cent; 195,800 to the bushel.

Chiquita.—Introduced from Hankow, China, 1910. Plants under favorable conditions semi-erect with twining terminals, maturing in about 135 days; pubescence tawny; flowers both purple and white, 65 to 70 days to flower; pods tawny, 35 to 45 mm. long, 8 to 9 mm. wide, 5 to 6 mm. thick, 2–3 seeded; seed straw-yellow, 6 to 7 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick; hilum brown; germ yellow; oil 17.6 per cent.; about 242,000 to the bushel.

Columbia.—Introduced from Paotingfu, China, 1908. Plants stout, erect, maturing in about 125 days; pubescence gray; flowers purple and white, 50 to 55 days to flower; pods gray, 40 to 50 mm. long, 8 to 10 mm. wide, 6 to 7 mm. thick, 2–3 seeded; seed green, 7 to 8 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick; hilum tawny; germ green; oil 18.7 per cent.; 200,000 to the bushels.

Early Brown.—Introduced by the Indiana Agricultural Experiment Station as a probable hybrid of Early Yellow (Ito San) and Early Black varieties. Plants stout, erect, maturing in about 110 days; pubescence tawny; flowers purple, 40 to 45 days to flower; pods tawny, 35 to 45 mm. long, 9 to 10 mm. wide, 6 to 7 mm. thick, 2–3 seeded, shattering little; seed brown, 7 to 8 mm. long, 6 to 7 mm. wide, 4 to 5 mm. thick; hilum brown; germ yellow; oil 17.7 per cent.; about 182,400 to the bushel.

Easycook.—Introduced from Shantung Province, China. Plants stout, erect, maturing in about 125 days; pubescence gray; flowers purple, 50 to 55 days to flower; pods gray, 45 to 55 mm. long, 10 to 12 mm. wide, 7 to 8 mm. thick, 2–3 seeded; seed straw yellow, 7 to 9 mm. long, 6 to 8 mm. wide, 6 to 7 mm. thick; hilum brown; germ yellow; oil 19.3 per cent.; about 162,200 to the bushel.

Ebony.—Introduced from Pingyang, Chosen (Korea), 1901. Plant stout, erect, maturing in about 120 days; pubescence tawny; flowers purple, 45 to 50 days to flower; pods brown, 6 to 7 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick; seeds 2–3, black, 6 to 7 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick; hilum black; germ yellow; oil 18.4 per cent.; 194,400 to the bushel.

Elton.—Introduced from Khabarovsk, Siberia, 1906. Plants stout, erect, maturing in about 110 days; pubescence gray; flowers purple, 35 to 40 days to flower; pods gray, 40 to 50 mm. long, 9 to 10 mm. wide, 6 to 7 mm. thick, 2–3 seeded; seed straw yellow, 8 to 9 mm. long, 6 to 7 mm. wide, 5 to 6 mm. thick; hilum pale; germ yellow; oil 17.4 per cent.; about 130,000 to the bushel.

Guelph.—Introduced from Japan, 1889. Plants stout, erect, maturing in about 115 days; pubescence tawny; flowers purple, 45 to 50 days to flower; pods brown, 40 to 50 mm. long, 10 to 11 mm. wide, 6 to 7 mm. thick, 2–3 seeded; seed green, 7 to 8 mm. long, 6 to 7 mm. wide, 5 to 6 mm. thick; hilum brown; germ green; oil 19.5 per cent.; about 149,000 to the bushel.

Hoosier.—Introduced from Wŭlŭkai, Manchuria, 1911. Plants stout, erect, maturing in about 115 days; pubescence tawny; flowers both purple and white, 35 to 40 days to flower; pods straw, 40 to 45 mm. long, 8 to 9 mm. wide, 6 to 7 mm. thick, 2–3 seeded, shattering little; seed straw yellow, 7 to 8 mm. long, 6 mm. wide, 5 mm. thick; hilum brown; germ yellow; oil 19.3 per cent.; about 150,700 to the bushel.

Haberlandt.—Introduced from Pingyang, Korea, 1901. Plants stout, erect, bushy, maturing in about 125 days; pubescence tawny; flowers both purple and white, 50 to 55 days to flower; pods brown, 40 to 50 mm. long, 9 to 10 mm. wide, 6 to 7 mm. thick, 2–3 seeded; seed straw yellow, 8 to 9 mm. long, 7 to 8 mm. wide, 6 to 7 mm. thick; hilum dark brown; germ yellow; oil 19.4 per cent.; 144,000 to the bushel.

Hamilton.—Introduced by the Ohio Agricultural Experiment Station as Ohio 9035. Plants stout, erect, maturing in about 125 days; pubescence tawny; flowers purple, 50 to 55 days to flower; pods brown, 45 to 55 mm. long, 10 to 11 mm. wide, 6 to 7 mm. thick, 2–3 seeded, shattering little; seed brown, 9 to 10 mm. long, 7 to 8 mm. wide, 5 to 6 mm. thick; hilum brown; germ yellow; oil 19.2 per cent.; 123,800 to the bushel.

Habaro.—Introduced from Khabarovsk, Siberia, 1906. Plants stout, erect, bushy, maturing in about 110 days; pubescence gray or tawny; flowers both purple and white, 35 to 45 days to flower; pods tawny or gray, 35 to 45 mm. long 9 to 10 mm. wide, 6 to 7 mm. thick, 2–3 seeded, shattering little; seed straw yellow, 8 to 9 mm. long, 6 to 7 mm. wide, 5 to 6 mm. thick; hilum brown; germ yellow; oil 19.6 per cent.; 188,200 to the bushel.

Hahto.—Introduced from Wakamatsu, Japan, 1915. Plants

stout, erect, bushy, maturing in about 130 days; pubescence tawny; flowers purple, 55 to 60 days to flower; pods brown, 60 to 80 mm. long, 13 to 15 mm. wide, 6 to 7 mm. thick, shattering little; seeds 2–3 olive yellow, 10 to 12 mm. long, 8 to 9 mm. wide, 5 to 6 mm. thick; hilum black; germ yellow; oil 17.9 per cent.; 74,800 to the bushel.

Hollybrook.—Selection from Mammoth about 1902 by T. W. Wood & Sons, Richmond, Va. Plants stout, erect, bushy, maturing in about 135 days; pubescence gray; flowers white, 60 to 65 days to flower; pods light, 35 to 45 mm. long, 9 to 10 mm. wide, 6 to 7 mm. thick, 2–3 seeded, shattering little; seed 6 to 7 mm. long, 5 to 6 mm. wide, 5 to 6 mm. thick; hilum light brown; germ yellow; oil 18.2 per cent.; 157,400 to the bushel.

Ito San.—Introduced from Japan, 1890. Plants stout, erect, bushy, maturing in 100 to 110 days; pubescence tawny; flowers purple; 40 to 45 days to flower; pods tawny, 35 to 45 mm. long, 9 to 10 mm. wide, 5 to 6 mm. thick, 2–3 seeded, shattering little; seed straw yellow, 7 to 8 mm. long, 6 to 7 mm. wide, 4 to 5 mm. thick; hilum pale; germ yellow; oil 16.9 per cent.; 198,900 to the bushel.

Laredo.—Introduced from Yangping, China, 1914. Plants slender, erect, maturing in about 140 days; highly resistant to wilt and nematode; pubescence tawny; flowers purple and white; 75 to 80 days to flower; pods 30 to 40 mm. long, 7 to 8 mm. wide, 3 to 4 mm. thick, 2–3 seeded; seed black, 6 to 7 mm. long, 4 to 5 mm. wide, 2 to 3 mm. thick; hilum black; germ yellow; oil 14.0 per cent.; 466,500 to the bushel.

Lexington.—Selection from Sherwood, 1907. Plants stout, erect, bushy, maturing in about 125 days; pubescence gray; flowers both purple and white, 50 to 55 days to flower; pods gray, 40 to 45 mm. long, 7 to 8 mm. wide, 5 to 6 mm. thick, 2–3 seeded; seed olive yellow, 7 to 8 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick; hilum tawny; germ yellow; oil 19.1 per cent.; 215,000 to the bushel.

Mammoth Yellow.—Nothing definite is known regarding the origin of this variety. Plants stout, erect, bushy, maturing in about 145 days; pubescence gray; flowers white; 85 to 90 days to flower; pods straw, 35 to 45 mm. long, 9 to 10 mm. wide, 7 to 8 mm. thick, 2–3 seeded; seed straw yellow, 7 to 8 mm. long, 6 to 7 mm. wide, 5 to 6 mm. thick; hilum tawny; germ yellow; oil 18.6 per cent.; 128,700 to the bushel.

Mammoth Brown.—Origin of this variety is rather obscure. Plants stout, erect, bushy, maturing in about 135 days; pubescence tawny; flowers purple, 65 to 70 days to flower; pods tawny, 40 to 50 mm. long, 9 to 11 mm. wide, 6 to 7 mm. thick, 2–3 seeded, shattering little; seed russet, 8 to 9 mm. long, 7 to 8 mm. wide, 5 to 6 mm. thick; hilum russet; germ yellow; oil 16.5 per cent., 111,300 to the bushel.

Manchu.—Introduced from Ninguta, Manchuria, 1913. Plants stout, erect, bushy, maturing in about 115 days; pubescence tawny; flowers both purple and white, 35 to 40 days to flower; pods tawny, 45 to 55 mm. long, 10 to 11 mm. wide, 7 to 8 mm. thick, 2–3–4 seeded; seed straw yellow, 8 to 9 mm. long, 6 to 7 mm. wide, 6 to 7 mm. thick; hilum black; germ yellow; oil 18.9 per cent.; 141,000 to the bushel.

Mandarin.—Introduced from Pehtuan lintza, Manchuria, 1911. Plants stout, erect, bushy, maturing in about 100 days; pubescence gray; flowers purple, 35 to 40 days to flower; pods gray, 40 to 50 mm. long, 9 to 10 mm. wide, 7 to 8 mm. thick, 2–3 seeded; seed straw yellow, 7 to 8 mm. long, 6 to 7 mm. wide, 5 to 6 mm. thick; hilum pale; germ yellow; oil 19.8 per cent., 174,700 to the bushel.

Medium Early Green.—The same as Guelph.

Medium Early Yellow.—The same as Ito San.

Medium Green.—The same as Guelph.

Medium Yellow.—The same as Midwest.

Merko.—Introduced from Merkoechofka, Siberia, 1906. Plants stout, erect, bushy, maturing in about 120 days; pubescence tawny and grey; flowers both purple and white, 40 to 45 days to flower; pods tawny, 35 to 45 mm. long, 8 to 9 mm. wide, 5 to 6 mm. thick, 2–3 seeded; seed olive brown, 8 to 9 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick; hilum olive; germ yellow; oil 16.4 per cent.; 294,600 to the bushel.

Minsoy.—Selection by the Minnesota Agricultural Experiment Station. Plants slender, erect, maturing in about 100 days; pubescence tawny; flowers purple, 30 to 35 days to flower; pods tawny, 35 to 45 mm. long, 7 to 9 mm. wide, 6 to 7 mm. thick, 2–3 seeded; seed straw yellow, 6 to 7 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick; hilum cinnamon brown; germ yellow; oil 16.3 per cent.; 221,700 to the bushel.

Midwest.—Introduced from Central China, about 1901. Appears identical with Medium Yellow, Roosevelt, Banner and

Northern Hollybrook. Plants stout, erect, bushy, maturing in about 115 days; pubescence tawny; flowers purple, 45 to 50 days to flower; pods tawny, 35 to 45 mm. long, 8 to 9 mm. wide, 5 to 6 mm. thick, 2–3 seeded; seed straw yellow, 6 to 7 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick; hilum tawny to cinnamon brown; germ yellow; oil 15.4 per cent.; 243,000 to the bushel.

Mikado.—Selection from Mongol by A. A. Parsons, Plainfield, Ind. in 1905. Plants stout, erect, bushy, maturing in about 120 days; pubescence tawny; flowers purple, 45 to 50 days to flower; pods tawny, 35 to 45 mm. long, 8 to 9 mm. wide, 6 to 7 mm. thick, 2–3 seeded; seed straw yellow, 7 to 8 mm. long, 6 to 7 mm. wide, 6 to 7 mm. thick; hilum cinnamon brown; germ yellow; oil 18.2 per cent.; 185,200 to the bushel.

Mongol.—The same as Midwest.

Morse.—Introduced from Newchwang, Manchuria, 1906. Plants stout, erect, bushy, maturing in about 130 days; pubescence gray; flowers both purple and white, 50 to 55 days to flower; pods gray, 35 to 45 mm. long, 8 to 9 mm. wide 6 to 7 mm. thick; 2–3 seeded, shattering little; seed olive yellow, 7 to 8 mm. long, 7 to 8 mm. wide, 5 to 6 mm. thick; hilum tawny; germ yellow; oil 18.1 per cent.; 149,700 to the bushel.

Ogemaw.—Introduced by E. E. Evans, West Branch, Mich., 1902 as a supposed cross between the Early Black and Dwarf Brown varieties. Plants stout, erect, bushy, maturing in about 85 days; pubescence tawny; flowers white, 30 to 35 days to flower; pods brown 40 to 50 mm. long, 9 to 10 mm. wide, 6 to 7 mm. thick, 2–3 seeded; seed chocolate, 8 to 9 mm. long, 6 to 7 mm. wide, 5 to 6 mm. thick; hilum chocolate; germ yellow; oil 17.5 per cent.; about 188,000 to the bushel.

Otootan.—Introduced from the Hawaiian Islands in 1911 by Prof. C. K. McClelland. Seed originally from Formosa. Plants slender, erect, bushy, maturing in about 170 days; pubescence tawny; flowers purple, 90 to 95 days to flower; pods tawny, 35 to 45 mm. long, 7 to 8 mm. wide, 4 to 5 mm. thick, 2–3 seeded; seed black, 6 to 7 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick; hilum black; germ yellow; oil 17.7 per cent.; 368,600 to the bushel.

Peking.—Selection from S.P.I. 17852 Peking, China, 1907. Plants slender, erect, bushy, maturing in about 120 days; pubescence tawny; flowers white, 50 to 55 days to flower; pods tawny, 40 to 50 mm. long, 8 to 9 mm. wide, 4 to 5 mm. thick, seeds 2–3, black 7 to 8 mm. long, 5 to 6 mm. wide, 3 to

4 mm. thick; hilum black; germ yellow; oil 16.0 per cent.; 383,300 to the bushel.

Pinpu.—Introduced from Harbin, Manchuria, 1910. Plants stout, erect, bushy, maturing in about 105 days; pubescence gray; flowers purple, 35 to 40 days to flower; pods gray, 45 to 50 mm. long, 7 to 8 mm. wide, 7 to 8 mm. thick, 2–3 seeded; seed straw yellow, 7 to 8 mm. long, 6 to 7 mm. wide, 6 to 7 mm. thick; hilum tawny; germ yellow; oil 18.4 per cent.; 160,300 to the bushel.

Sable.—Same as Peking.

Tarheel Black.—Introduced from Shanghai, China, 1905. Plants stout, erect, maturing in about 140 days; pubescence tawny, flowers purple and white, 70 to 75 days to flower; pods brown 45 to 55 mm. long, 9 to 10 mm. wide, 6 to 7 mm. thick, 2–3 seeded, shattering little; seed black, 9 to 10 mm. long, 7 to 8 mm. wide, 6 to 7 mm. thick; hilum black; germ green and yellow; oil 18.6 per cent.; about 163,200 to the bushel. Originally named "Shanghai."

Tokio.—Introduced from Tokio, Japan, 1901. Plants stout, erect, maturing in about 145 days; pubescence gray; flowers both purple and white, 70 to 75 days to flower; pods gray, 40 to 50 mm. long, 10 to 12 mm. wide, 6 to 7 mm. thick, 2–3 seeded, shattering little; seed olive yellow, 7 to 8 mm. long, 6 to 7 mm. wide, 5 to 6 mm. thick; hilum pale; germ yellow; oil 18.4 per cent.; about 134,400 to the bushel.

Virginia.—Selection from the Morse, 1907 (Fig. 44). Plants slender, erect; the tips twining, maturing in about 125 days; pubescence tawny; flowers purple, 50 to 55 days to flower; pods tawny, 40 to 50 mm. long, 8 to 9 mm. wide, 5 to 6 mm. thick, 2–3 seeded; seed olive, 8 to 9 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick, hilum olive; germ yellow; oil 17.9 per cent.; about 207,300 to the bushel.

Wilson.—Introduced from Newchwang, Manchuria, 1906. Plants slender, erect, maturing in about 120 days; pubescence gray and tawny; flowers both purple and white, 50 to 55 days to flower; pods brown, 40 to 50 mm. long, 8 to 9 mm. wide, 5 to 6 mm. thick, 2–3 seeded; seed black, 7 to 9 mm. long, 6 to 7 mm. wide, 4 to 5 mm. thick; hilum black; germ green and yellow; oil 18.4 per cent.; 144,000 to the bushel.

Wilson-Five.—Selection from Wilson, 1912. Plants slender, erect, maturing in about 120 days; pubescence gray; flowers

white, 50 to 55 days to flower; pods gray, 50 to 55 mm. long, 8 to 9 mm. wide, 4 to 5 mm. thick, 2–3 seeded; seed black, 7 to 8 mm. long, 5 to 6 mm. wide, 3 to 4 mm. thick; hilum black; germ yellow; oil 15.2 per cent.; about 301,400 to the bushel.

Wisconsin Black.—A selection developed from an Early Black variety by the Wisconsin Agric. Exper. Sta. Plants stout, erect, maturing in about 100 days; pubescence tawny; flowers purple, 30 to 35 days to flower; pods brown, 40 to 50 mm. long, 8 to 10 mm. wide, 6 to 7 mm. thick, 2–3 seed; seed

FIG. 44.—A field of the Virginia variety of soybeans.

black; 8 to 9 mm. long, 5 to 6 mm. wide, 4 to 5 mm. thick, hilum black; germ yellow; oil 17.7 per cent.; about 185,200 to the bushel.

Wea.—Introduced from Shuangchengpu, Manchuria, 1911. Plants stout, erect, maturing in about 110 days; pubescence gray; flowers purple, 35 to 40 days to flower; pods gray, 40 to 45 mm. long, 7 to 8 mm. wide, 6 to 7 mm. thick, 2–3 seed; seed straw yellow, 7 to 8 mm. long, 6 to 7 mm. wide, 5 to 6 mm. thick; hilum dark olive; germ yellow; oil 19.6 per cent.; about 194,880 to the bushel.

Yokotenn.—Introduced from Yokohama, Japan, 1907. Plants stout, erect, maturing in about 120 days; pubescence gray; flowers both purple and white, 50 to 55 days to flower; pods gray, 40 to 50 mm. long, 10 to 11 mm. wide, 6 to 7 mm. thick, 2–3 seed; seed straw yellow, 7 to 8 mm. long, 6 to 7 mm. wide, 5 to 6 mm. thick; hilum cinnamon brown; germ yellow; oil 19.9 per cent.; about 70,000 to the bushel.

KEY FOR THE IDENTIFICATION OF VARIETIES

I. Yellow Group

Seeds Straw Yellow

Hilum pale
- Seed 4–5 mm. thick..............A. K.
- Seed 5–6 mm. thick
  - Seed 7–8 mm. long..........Ito San
  - Seed 8–9 mm. long..........Aksarben
  - Seed 9–10 mm. long.........Elton
- Seed 6–7 mm. thick............Mandarin

Hilum tawny
- Seed 6–7 mm. long...............Hollybrook
- Seed 7–8 mm. long
  - Hilum less than 1 mm. wide....Pinpu
  - Hilum more than 1 mm. wide..Mammoth

Hilum cinnamon brown
- Seed 4–5 mm. thick
  - Seed 6–7 mm. long............Minnsoy
  - Seed 7–8 mm. long............Chiquita
- Seed 5–6 mm. thick..............Hoosier
- Seed 6–7 mm. thick
  - Seed 6–7 mm. long............Mikado
  - Seed 7–8 mm. long
    - Hilum 3 mm. long..........Yokotenn
    - Hilum 4 mm. long...........Easycook

Hilum tawny to cinnamon brown....Midwest

Hilum dark olive...................Wea

Hilum dusky brown
- Seed 5–6 mm. thick..............Habaro
- Seed 6–7 mm. thick..............Haberlandt

Hilum black......................Manchu

Seeds Olive Yellow

Hilum pale.......................Tokio

Hilum tawny
- Seed 6–7 mm long...............Lexington
- Seed 7–8 mm. long...............Morse

Hilum black......................Hahto

II. Green Group

Seeds Chromium Green
- Seed 6–7 mm. long...............Columbia
- Seed 7–8 mm. long...............Guelph

III. Brown Group

Seeds Olive
- Seed 6–7 mm. long.............Barchet
- Seed 8–9 mm. long
  - Seed 4–5 mm. thick...........Virginia
  - Seed 5–6 mm. thick...........Merko

Seeds Russet
- Seed 6–7 mm. thick.............Chestnut
- Seed 7–8 mm. thick.............Mammoth Brown

Seeds Auburn
- Seed 7–8 mm. long.............Early Brown
- Seed 8–9 mm. long.............Hamilton

Seeds Chocolate.
- Seed 8–9 mm. long.............Ogemaw
- Seed 10–11 mm. long...........Biloxi

IV. Black Group

- Seed 2–3 mm. thick.............Laredo
- Seed 3–4 mm. thick
  - Seed 4–5 mm. wide...........Peking
  - Seed 5–6 mm. wide...........Wilson-Five
- Seed 4–5 mm. thick
  - Seed 6–7 mm. long...........Ebony
  - Seed 8–9 mm. long...........Wisconsin Black
- Seed 5–6 mm. thick
  - Seed 6–7 mm. long...........Otootan
  - Seed 8–9 mm. long...........Tarheel Black

V. Bicolored Group.

Seeds Black and Brown
- Black with brown saddle.......Black Eyebrow
- Black and brown in concentric bands......................Meyer

Seeds Black and Olive Yellow
- Black with olive yellow saddle..Taha

Breeding and Improvement.—The soybean lends itself readily to improvement. Considerable breeding work has been carried on by the United States Department of Agriculture and by the State Experiment Stations. Very little work along this line seems to have been done in Oriental countries. Recently in

Manchuria something has been done toward the improvement of varieties and the establishing of pure strains. Terao (1918) has studied the behavior of artificial hybrids in Japan. Although the Orient abounds with varieties, it is evident that they are the results of natural crossing and selection.

The testing of the progeny of individual plants in the United States has shown decided differences in yield of forage and seed, in tendency to shatter, in habits of growth, in maturity, and in oil and protein content. Several new varieties (Virginia, Peking, Chestnut, Hamilton, Wisconsin Black) have been introduced into the seed trade of the United States as a result of selection work. Some of these sorts originated from natural hybridization and a few are almost certainly mutations or sports. Valuable new sorts of the soybean will doubtless be secured through artificial hybridization and selection.

Layosa (1918) has carried on the breeding work with soybeans begun by Maceda in the Philippines to determine their commercial value and to ascertain those sorts best suited for the rainy and for the dry seasons, respectively. It was found that selections from Kedilcie Wit grown during the rainy season and strains from Ami grown during the dry season produced the highest yields. Seed obtained from a rainy season culture of Kedilcie Wit and grown during the dry season resulted in a lower yield than that obtained during the rainy season. Morona Maceda (1919) conducted a series of experiments with the soybean along the following lines: (1) The multiplication of strains selected by Layosa and the running of "plant to row" tests of the most productive individuals or elites of each strain; (2) the isolation of strains that can be recommended for the rainy or dry season under local conditions; and (3) the comparison of the yield of selected strains with that of unselected plants. Each of the strains selected by Layosa gave higher yields in beans than their respective parents. With two exceptions all selected strains gave higher yields than the common stock. The gain in percentages of the yield of the selected strains over the common sort ranged in multiplication plantings from 18 per cent. to 79 per cent.

Pollination.—The soybean is normally a self-pollinated plant. The flowers are completely self-fertile, as bagged or screened plants set pods and seeds as perfectly as in the open. This proved true of 30 plants representing ten varieties thus tested at

Arlington Experimental Farm, Va., in 1909. Similar experiments carried on by Woodhouse and Taylor (1913) in India gave identical results.

The flowers are much visited by bees, mainly for pollen, as but a very small amount of nectar is secreted. Cross-pollination would be of frequent occurrence were it not for the fact that the abundant pollen of each flower covers the stigma about as soon as the flower opens. Under Arlington Farm, Virginia, conditions in tests where rows of different varieties are contiguous so that full opportunity is afforded for natural cross-pollination, it is only in occasional seasons that as much as 1 per cent. of the seeds show evidence of crossing. In general, it has been assumed that 1 or 2 per cent. of natural cross pollination occurs in soybeans. Experiments by L. J. Cole (1919) indicate that it is much less frequent in Wisconsin. Pure line strains with distinctive characters were planted alternately in the same row, and of over 6,500 pods examined, only three showed evidence of cross.

Mutations.—The origin of new varieties of soybeans without hybridization has apparently occurred in certain cases that have come under observation. From a theoretical standpoint there can be no doubt that the fundamental diversity in a plant, especially when normally selfpollinated, is brought about by other causes than hybridization. It is self-evident that there must be two varieties to cross before crossing can become effective in producing new varieties. Most soybean varieties when pure, remain very constant to type, so that any chance variation is quickly detected. There are two cases in which the evidence is fairly satisfactory that a brown-seeded variety arose as a mutation from a yellow seeded sort.

The Trenton is a brown-seeded variety found in a field of the yellow-seeded Mammoth grown in Kentucky. Grown side by side at the Arlington Experimental Farm, the two sorts were indistinguishable by any other character than the seed color. The Riceland variety has been grown at the Arlington Experimental Farm for several seasons, and while it matures few seeds, it is very uniform. At Biloxi, Miss., in 1908 it displayed astonishing diversity. Some plants had very narrow leaves, others very broad, and all degrees of intermediates occurred; some plants were erect, others procumbent; some fruited heavily, others scarcely at all. The seed was saved from individual plants showing the most striking variations, and the resultant plants

of each in 1909 were uniform. It is possible that the seed planted at Biloxi contained these forms, but the fact that the same bulk seed gave uniform plants elsewhere, indicates that the diversity was a response to the environment. No similar phenomenon has as yet been witnessed in other varieties.

Natural Hybridization.—Previous to 1907, the remarkable uniformity of the commonly cultivated varieties of soybeans had led to the belief that natural hybridization in the soybean did not occur. This was apparently confirmed by the uniformity of plots of many varieties planted side by side during several

Fig. 45.—Seeds of a natural soybean hybrid showing peculiar types of coloration.

successive seasons at Arlington Experimental Farm, Va. In 1907, however, there were noted in the yield from several plots and rows, certain oddly-colored seeds, such as smoky-yellow, smoky-green, brown and yellow, etc. These seeds were saved and the resultant row of each in 1908 gave diverse progeny, showing that some of the seeds were hybrid and heterozygous. In 1908 more than 100 single plant selections of supposed hybrids were made and planted in separate rows in 1909. The resultant data showed that most of these broke up in simple Mendelian proportions, thus confirming the suspicion that they were in reality hybrids.

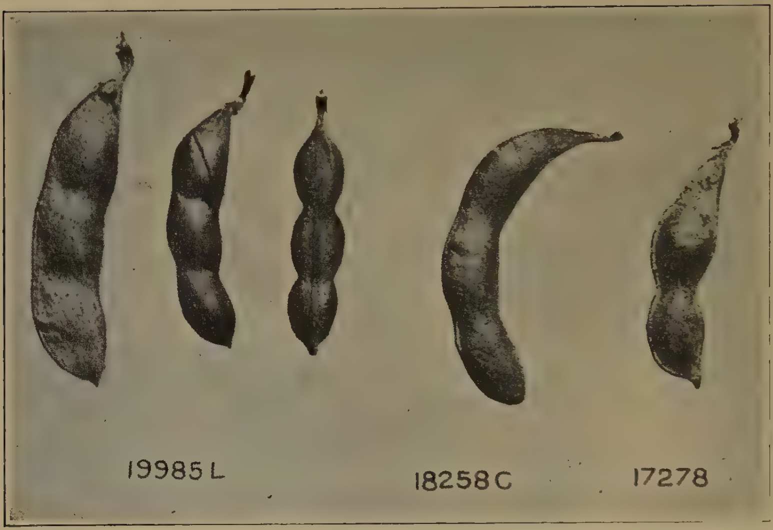

FIG. 46.—Pods of soybeans: No. 19985 L, hairy and smooth from one heterozygote individual; No. 18258 C and No. 17278, smooth pods from heterozygote plants.

FIG. 47.—A sterile soybean plant obtained from a natural hybrid.

Natural hybrids are rather easily detected by the peculiar coloration of the seeds (Fig. 45). Among the more striking colors are yellow or green with a single narrow transverse band of brown or black; yellow or green with an irregularly star-shaped figure centering at the hilum; and green or yellow more or less suffused with a smoky color beginning at the hilum and extending over half or more of the seed, or mainly centered about the hilum. Some of the last breed true but most of them do not. The other colors give a diverse progeny as to seed color, none of them like those of the parent plant, which is therefore heterozygous. The heterozygous plants, with seeds wholly or mainly yellow, are often distinguished by the unusual form of the pods near the tips of the branches (Fig. 46). Such pods are more tumid and the seeds more crowded. Often these pods are thinner-walled and much less hairy, sometimes nearly smooth. Very often sterile plants were found to occur in the different hybrid selections (Fig. 47).

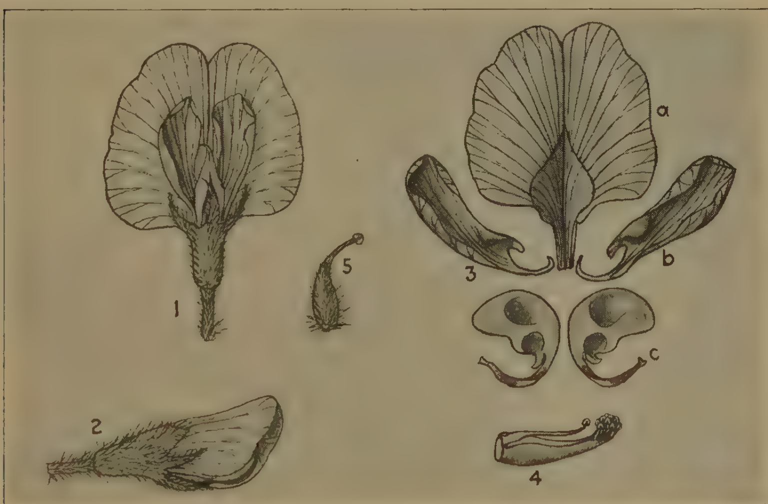

Fig. 48.—Flower of the soybean enlarged. 1. Front view. 2. Side view. 3. Parts of the corolla; *a*, standard; *b*, wing; *c*, one of the keel petals. 4. Stamens. 5. Pistil.

Artificial Hybridization.—Since 1909 numerous artificial crosses have been made between varieties of soybeans. The work of crossing is rather difficult owing to the very small flower and the ease with which it is injured. Under field conditions successful

crossings have been made in about 20 per cent. of the operations. In the greenhouse, where it is difficult to secure normal behavior in the soybean plant in winter, no success has thus far attended efforts to produce hybrids.

Experience has shown that the emasculation must be performed before the soybean flower (Fig. 48) has fully opened. All of the flower buds are removed from the raceme except three or four, of which the purple or white of the corolla appears above the calyx. At this stage, the anthers of which there are ten surrounding the stigma, are immature and may be easily removed with tweezers without bursting the sacs. The corolla is readily removed by grasping the tip with the tweezers, slightly turning and pulling it. The removal of the whole corolla in this manner exposes the anthers and greatly facilitates their removal. After emasculation, pollen may be applied at once with a brush or a toothpick. In collecting the pollen for crossing, it is advisable to select flowers just before they open. After the pollen has been applied, the raceme should be enclosed in a small mosquito netting bag and tied so as to exclude the visits of insects. It is well to apply pollen again the following day.

Genetic Behavior.—Considerable data have been collected in the behavior of selections from natural and artificial hybrids. In presenting the most important features of this work, the results are taken up under the various plant characters.

TABLE LXXV.—BEHAVIOR OF FLOWER COLOR IN NATURAL HYBRIDS

Purple-flowered plants			White-flowered plants		
Selection number	Progeny		Selection number	Progeny	
	Purple	White		White	Purple
1	186	50	1	239	6
2	85	24	2	120	35
3	79	27	3	332	1
4	122	40	4	120	2
5	103	37	5	53	1
6	32	10	6	59	1
7	65	25	7	126	1
8	61	26	8	143	2
9	82	19	9	8	1
10	28	11	10		
Total......	843	269	...	1,200	50

Flower Color.—The color of flower is quite often the only distinguishing character between plants. In a large proportion of the varieties experimented with, both purple-flowered and white-flowered strains occurred in the same variety, or in other words the variety was not pure. It was found that purple-flowered plants predominated in nearly all instances. Of 90 purple-flowered plant selections in 1912, 68, or 75 per cent. bred true, that is, gave purple-flowered progeny. With 33 white-flowered plant selections, 25, or 69 per cent. gave white-flowered progeny. Table LXXV shows the results obtained with 10 purple-flowered plants and 10 white-flowered plants of hybrid origin.

In artificial hybridization the flower color has been found to separate according to simple Mendelian ratio, the purple flowers being dominant.

Pubescence.—No marked degree of difference in the amount of pubescence has been noted with the numerous varieties of soybeans, with the exception of a variety received from Japan. This variety has very little pubescence and is the nearest approach to a smooth variety (see Fig. 39). In the breeding work it has been noted both in natural and artificial hybrids that the heterozygous plants bear nearly smooth pods at the ends of the

Table LXXVI.—Behavior of Pubescence Colors in Natural Hybrids

Tawny pubescent selections			Gray pubescent selections		
Selection number	Progeny		Selection number	Progeny	
	Tawny	Gray		Tawny	Gray
1	180	56	1	49	1
2	90	16	2	160	2
3	17	6	3	127	3
4	207	58	4	324	9
5	164	54	5	130	1
6	80	28	6	75	1
7	26	16	7	53	1
8	87	35	8	143	2
9	47	10	9	37	14
10	88	32	10	217	1
Total......	986	311	..	1,315	36

main stem and branches. With some of these plants branches occur which have nearly all smooth pods.

In 1912, of 81 plants selected with tawny pubescence, 62 or 75 per cent. bred true and of 37 plants with gray pubescence, 24 or 66 per cent. bred true. Table LXXVI gives the results obtained with 10 plant selections with tawny pubescence and 10 plants with gray pubescence.

With artificial hybrids, the colors of pubescence have behaved the same as with natural hybrids. The hybridization of the nearly smooth variety (a very slight amount of gray pubescence) with the Guelph or Medium Green, a very pubescent sort, gave results showing amount of pubescence to be a character behaving much the same as color character. Selection of nearly smooth forms in continued generations has given pure, nearly smooth podded plants, having all characteristics of the Guelph (green seeded) except the near-smoothness of the Japan sort (yellow seeded).

The following table gives the results obtained with some of the plants selected in the first generation.

Table LXXVII.—Behavior of Amount and Colors of Pubescence in an Artificial Hybrid

Hybrid number	Amount and color of pubescence						
	Much			Medium			Nearly smooth
	Tawny	Gray	Total	Tawny	Gray	Total	Total
5696–2	42	40	82	..	127	127	2
5696–4	17	..	17	..	40	40	15
5696–8	10	28	38	..	..	..	15
5699–4	19	39	58	..	..	..	18
5699–5	42	71	113	..	8	8	15
5699–7	46	..	46	..	94	94	33
5700–2	26	96	122	..	..	..	43
5696–12	4	3	7	..	64	64	11

Color of Pods.—The color of the pods has been studied especially with the progeny of the cross between the near-smooth from Japan and the Guelph. The Guelph has very dark brown pods, approaching black, while the other variety has light or straw-colored pods. The following table shows the manner in which these colors behaved in the progeny.

TABLE LXXVIII.—BEHAVIOR OF THE COLOR OF PODS IN NATURAL HYBRIDS

Selection number	Color of pods	
	Dark	Light
5700–2	99	26
5700–5	71	33
5699–2	70	15
5699–1	141	37
5696–4	17	55
5696–3	27	9

Color of Seeds.—Individual selections of natural hybrids have given rather interesting results in the breaking up of the various seed colors and peculiar types of coloration (Fig. 49). Those

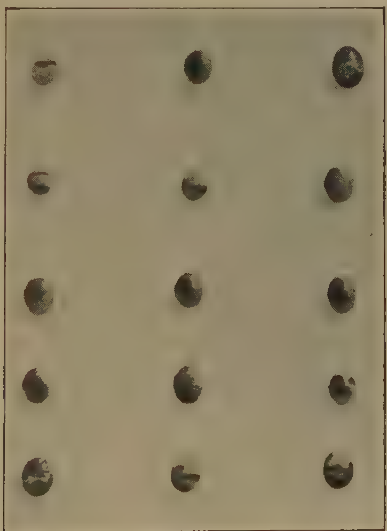

FIG. 49.—Seeds of an artificial soybean hybrid, showing peculiar types of coloration.

selections with a single seed color as straw yellow, olive yellow, black or brown, break up in simple Mendelian proportions, while those selections with more than one color present a different ratio in the progeny. It is quite evident that the selections made were first generation hybrids. Table LXXIX gives the results obtained with natural hybrids representing different seed colors.

Table LXXIX.—Behavior of Seed Colors in Natural Hybrids

Selection number	Parent	Seed color — Progeny: S.Y.	O.Y.	G.	Bl.	Br.	Bl. & Br.	S.Y. & Br.	S.Y. & Bl.	O.Y & Bl	O.Y. & Br.	S.Y. to O.Y.	S.Y. to G.	O.Y., Bl. & Br.
5504–2	S.Y.	99	2	..	..	40	..	1	..	..	1			
5526–4	S.Y.	85	...	..	26	9	..	5	13	..				
5657–7	S.Y.	47	...	..	..	31	..	..	..	..	..	..	..	21
5501–1	O.Y.	..	171	..	1	59								
5501–4	O.Y.	..	66	..	..	37	..	..	..	..	6			
5657–1	S. to O.Y.	..	..	..	..	16	..	..	..	..	..	28		
5657–4	S. to O.Y.	..	..	..	..	54	..	..	..	..	..	161		
5521–3	G	..	..	30	..	12								
5521–6	G	..	..	52	..	23								
5501–2	Br.	..	1	..	..	49								
5502–5	Br.	..	..	..	..	127	3							
5657–14	Br.	13	..	..	..	25	7							
5501–5	Bl.	..	..	..	88	16								
5504–1	Bl.	..	..	..	86	88	44							
5526–7	Bl.	..	..	..	167	51								
5522–18	S.Y. to G.	16	..	10	..	..	..	..	..	..	..	..	29	
5522–5	S.Y. to G.	13	..	13	..	22								
5501–3	O.Y. & Bl.	..	163	..	53	15	..	..	..	5				
5522–4	O.Y. to G. & Br.	28	49	26	..	24								
5522–6	S. to O.Y. & Br.	11	16	7	..	17								
5526–9	S. Y. Bl. & Br.	59	..	..	..	8	14	4	10					
5526–12	O.Y. & Bl.	..	72	..	36	12	..	..	10	21				
5526–14	Bl. & Br.	..	..	..	15	17	34							

S.Y. = straw yellow
O.Y. = olive yellow
G. = green
Bl = black
Br. = brown

The progeny of artificial hybrids has been found to be diverse in the same manner as that of the selected natural hybrids and to yield seeds showing peculiar markings (Fig. 46). The results obtained with numerous crosses have been similar to those of Terao (1918). Table LXXX shows the results obtained with a few crosses by the junior author and by Terao.

TABLE LXXX.—SOYBEAN CROSSES IN THE STUDY OF SEED COLOR

	Cross No.[1]		Cross No. 2[1]	Cross No. 3[2]	Cross No. 4[2]	
	Color of seed		Color of seed	Color of seed	Color of seed	
Parents:						
Female	Black		Green	Green	Yellow	
Male	Brown		Yellow	Yellow	Green	
F_1 plant	Black		Green	Green	Green	
F_2 plant	Black	Brown	Green	Green	Green	Yellow
No. of plants	170	62			825	288
	(73.3%	26.7%)			(74.1%	25.9%)

Terao has proved in crossing experiments the inheritance of the seed coats to be maternal as shown in the above table. The inheritance of the seed coat colors was found more complicated than that of the color of cotyledon of which also a study was made. In the cross, green seed-coat (♀) × "yellow seed-coat" (♂), the green seed-coat is inherited through the female parent exclusively but in the reciprocal cross the green and yellow seed-coats show Mendelian segregation, the former being dominant. With a cross between Guelph or Medium Green (♀) and a yellow seeded sort (♂) similar results were obtained, the seed coat being green through several generations.

Color of Cotyledons.—The behavior of the green and yellow cotyledons in natural and artificial hybrids has given some very interesting results. In the fall of 1909 it was noted in the hybrid selections work that with many straw-to-olive yellow seeded plants, seeds with green cotyledons and seeds with yellow cotyledons occurred on the same plant and sometimes in the same pod. The results obtained from planting several individual plant selections are shown in the following table.

[1] Crosses made by junior author.
[2] Crosses made by Terao.

Table LXXXI.—Behavior of Cotyledons in Natural Hybrid Selections

Plant selection number	Parent	Color of cotyledons — Progeny: Green, number of plants	Yellow, number of plants	Green and yellow, number of plants
3390	Yellow and green	7	18	27
3542	Yellow and green	4	8	22
5522–1	Yellow	. .	54	
5522–2	Yellow and green	22	23	24
5522–4	Yellow and green	33	39	55
5522–5	Yellow and green	19	22	36
5522–6	Yellow and green	14	17	20
5522–7	Yellow	15	12	27
5522–11	Yellow and green	17	19	25
5522–12	Yellow and green	8	16	24
5522–13	Yellow and green	10	16	29
5522–14	Yellow and green	28	49	68

Terao (1918) in a number of crosses has proved that the inheritance of green and yellow cotyledons to be maternal. It was found that the F_1 cotyledons of the crosses reciprocal to each other are of the same character as the female parent. In respect to the cotyledon colors, the F_2 and following generations show the characters of the F_1 generations exclusively, instead of a Mendelian segregation between the yellow and green colors. It is concluded that characters are being dealt with which can be inherited only through the female parents as shown in Table LXXXII. In a further discussion of these characters, it is stated that the F_2 families of the crosses were actually composed of two kinds of individuals which were distinguishable from each other by a slight difference of the intensity of the green color in the seed coats, and the numerical relation between these two kinds of individuals was approximately the Mendelian monohybridal segregation ratio. By using individuals from previous experiments representing different intensities of seed-coat color as the parents, phenomena different from crosses 1, 2 and 3 were obtained. Results obtained by the junior author and by Terao with artificial hybrids are shown in detail in Table LXXXII.

TABLE LXXXII.—BEHAVIOR OF COTYLEDONS IN SOYBEAN CROSSES

	Cross No. 2[1]	Cross No. 2[1]	Cross No. 3[1]	Cross No. 5[2]
Parents:				
Female	Green	Yellow	Yellow	Green
Male	Yellow	Green	Yellow	Yellow
F_1 plant	Green	Yellow	Yellow	Green
Number plants	24	40	5	
F_2	Green	Yellow	Yellow	Green
Number plants	constant	constant	constant	constant

Oil Content.—In pure line selection work with soybeans for high and low percentage of oil and high and low iodine number as a measure of the relative value of the oil for use in paint manufacture, results obtained at the Wisconsin Experiment Station failed to lead to the development of strains having consistently high and low oil percentages. In 1918, L. J. Cole (1919) found the average iodine number of 56 plants in the high-selection line to be 136.6 and that of 43 plants in the low-selection line 125.1, the first appearance of a distinct difference between the two lines. E. M. Nelson found that the amount and the iodine number of the oil in the leaves of soybean plants was also subject to considerable variation, the amount of ether extract ranging from 3.7 to 6 per cent. Analyses of soybean selections from the seventh year's work at this station (1919–20) for increased oil content showed a high-line strain and a low-line strain, with iodine indices of 132 and 124, respectively, indicating the effect of selection. The low-line strain was entirely of a dwarf type, while the high strain consistently produced both tall and dwarf types, pointing to a definite relation between plant height and quality of oil. A high-producing strain as well as a low-producing strain has been isolated.

The breeding work for oil content was abandoned when it was discovered that the environment under which the beans were grown made the oil content variable.

Selection work with the Mammoth Yellow variety for increased oil content has been carried on by the North Carolina Experiment Station[3] since 1916. The oil content on a dry basis of the

[1] Crosses made by Terao.

[2] Crosses made by junior author.

[3] Data furnished by Dr. R. Y. Winters in charge of the work.

progeny of selections made in 1916 ranged between 13.63 per cent. and 22.86 per cent. in 1917. The protein contents of these plants were respectively 47.41 per cent. and 37.38 per cent., the protein decreasing as the fat increased. The yield per acre ranged from 15 to 35 bu. In 1918 larger plots were planted in two series, all of the strains being included. From composite samples of each of these strains the oil content ranged from 16.11 to 18.78 per cent. In 1919 the range from the same strains was 17.02 to 19.17 per cent. The highest yielding strains regardless of the oil content, and the strains giving the largest oil content were retained. The results of the work with the number of strains under test led to the conclusion that the greatest quantity of oil per acre is secured from the highest yielding strains rather than from the high oil strains. However, it was felt that with a larger number of oil determinations high oil content in high yielding strains might be obtained.

The Agricultural Experiment Station of the South Manchuria Railway at Szupingkai, Manchuria, has conducted experiments with high oil yielding strains for several years. Two strains containing more than 20 per cent. oil, and being uniform in shape and size have become widely distributed in Manchuria. These strains are said to yield 15 to 20 per cent. greater crops than varieties generally grown. When a strain has been thoroughly tested out and its value established, the station places all of the seed with a grower and requires that he grow no other variety. The entire crop is purchased by the station and the seed distributed to more growers that agree to grow only the one variety. The seed then is placed in general distribution at a moderate price.

CHAPTER X

STRUCTURE OF SOYBEAN SEEDS

The structure of the soybean seed has been thoroughly examined by several botanists. The various tissues composing the seeds are much like those of other beans, but the oil containing cells are peculiar. There are differences enough, however, in the cellular structures so that it is relatively easy to detect adulteration of soybean meal.

The Structure of the Soybean Seed.—The microscopic structure of the soybean has been examined by several investigators, notably Harz (1885), Kondo (1913), and Wallis (1913). The gross structure of the seed is much like that of related plants.

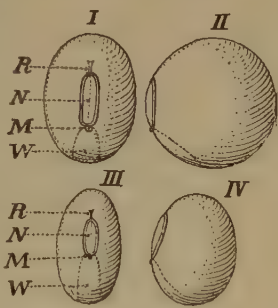

FIG. 50.—Soybean seed. I, II. A yellow variety from Japan. III, IV. Another variety. *N*, hilum; *R*, chalaza; *M*, micropyle; *W*, outline of hypocotyl seen through the testa. (*After Kondo.*)

The Seed Coat.—The seed coat is smooth, often shiny, rather firm in texture, and closely enveloping the embryo. The *hilum* or seed scar is linear-elliptical in shape and nearly flat (Fig. 50). At one end is a small linear grove marking the *chalaza*, *R*. or point where the seed coat was joined to the body of the ovule. At the other end of the hilum is the *micropyle*, *M*. a minute orifice in the seed coat, through which the primary root of the young seedling emerges in germination. In many varieties of soybean the outlines of the *hypocotyl*, *W*. may be seen through the seed coat.

Microscopic Structure of the Seed Coat—The cellular structure of the seed coat or *spermoderm* is shown in the accompanying illustration (Fig. 51). The seed coat consists of four layers of cells, namely the palisade cells, *P*, the hour-glass or column cells, *Sz*, the spongy parenchyma *Sp*, and the aleurone layer *A*.

The palisade cells are about equal in size, 40 to 60 microns long and one-third to one-fourth as much in diameter. The outer walls

have a definite cuticular layer, *C*. In cross section the walls are seen to be thick and with 5 to 7 radiating lines to each cell. The cell walls are always colorless, but in green, brown, or black varieties, the corresponding color is found in the lumen or cavity of each palisade cell.

The hour-glass or column cells form the second layer of the seed coat. The cells are shaped like hour-glasses, each end being

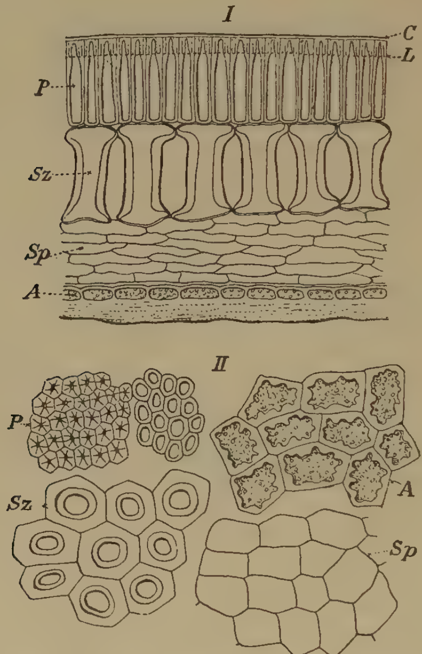

FIG. 51.—Cross-section of the testa of a yellow soybean. II. Horizontal section of same. *C*, cuticle; *L*, light-line; *P*, palisade cells; *Sz*, hour-glass cells; *sp*, spongy parenchyma. *A*, aleurone layer. (*After Kondo.*)

hexagonal. Owing to the form of the cells there are large intercellular spaces in this layer. The hour-glass cells are a little longer than the palisade cells, varying from 30 to 70 microns. Both the cells and the intercellular spaces are empty. The hour-glass cells separate readily and by their characteristic form and size furnish one means of identifying soybean meal.

The spongy parenchyma consists of 6 to 8 layers of thin-walled, somewhat compressed, box-like, empty cells, ranging in width from 20 to 120 but mostly 40 to 60 microns.

The aleurone layer consists of a single series of moderately thick-walled cells with dense protein (aleurone) contents. In a tangential section the aleurone cells are seen to be rectangular or polygonal. Beneath this layer of cells are others which are nearly obliterated by compression and appear like obscure fibers.

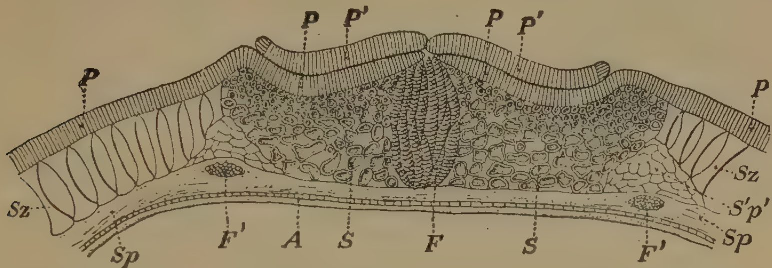

FIG. 52.—Cross-section of hilum of a yellow soybean from China. *Pl*, outer palisade layer; *P*, inner palisade layer; *S*, asteroid parenchyma; *Sp*, spongy parenchyma; *F*, fibro-vascular bundle; *F*, fibro-vascular bundle of the testa; *A*, aleurone layer; *Sz*, hour-glass cells. (*After Kondo.*)

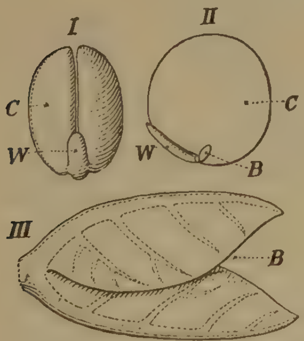

FIG. 53.—Embryo of a yellow soybean seed from Japan. I. Whole embryo from the ventral side. II. Half of embryo seen from the inner side. III. The two leaves of the plumule. *C*, cotyledons; *W*, hypocotyl; *B*, leaves of plumule. (*After Kondo.*)

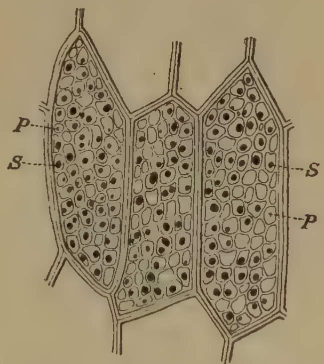

FIG. 54.—Soybean. Cells of the cotyledon filled with fat, protein and starch; *P*, protein; *S*, starch. (*After Kondo.*)

Microscopic Structure of the Hilum.—The cellular structure of the hilum is shown in the accompanying illustration (Fig. 52). The most striking features in its structure are (1) the double outer layers of palisade cells; (2) the fibro-vascular bundle, consisting

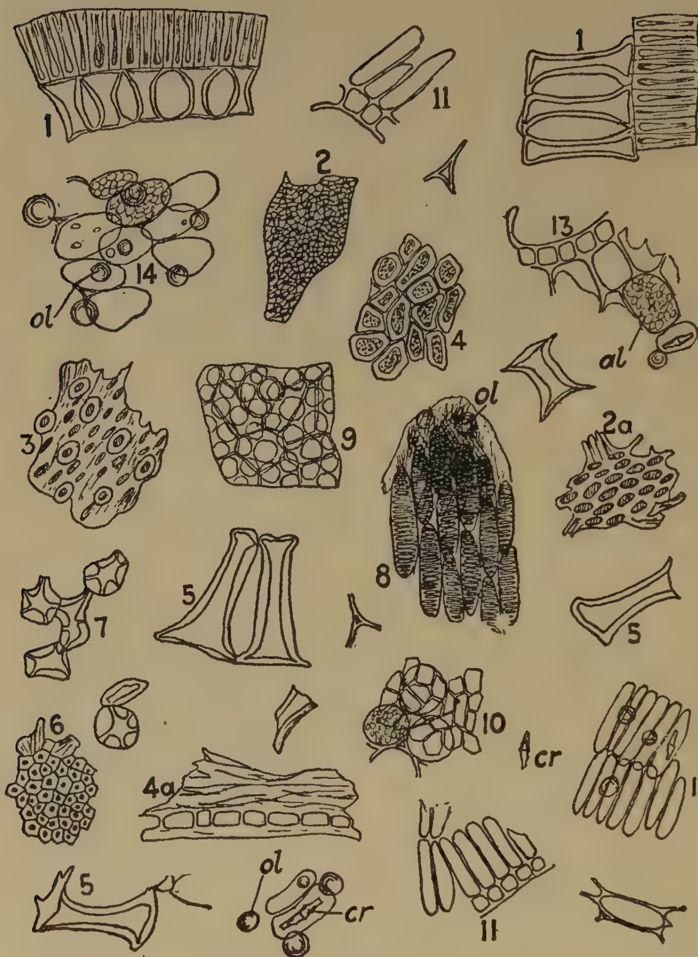

Fig. 55.—Cellular structure found in soybean flour and meal.

1, Palisade and hour-glass cells in sections. 2, Palisade cells in surface view from above. 2*a*, Same from below. 3, Same with a few hour-glass cells attached. 4, Aleurone cells within seed-coat. 4*a*, The same with compressed parenchyma in section. 5, Hour-glass cells. 6, Surface view of epidermal cells near the hilum. 7, Parenchyma from near the hilum. 8, Tracheids from hilum furrow. 9, Epidermis and underlying cells from flat side of cotyledon. 10, Epidermis and underlying cells from rounded side of cotyledon. 11, Epidermis and palisade cells in transverse section of cotyledon. 12, Palisade cells from cotyledon. 13, Epidermis and mesophyll cells from rounded face of cotyledon. *Ol*, oil drop; *Cl*, crystal; *Al*, aleurone grains. (*After Wallis.*)

mainly of spindle-form tracheids with reticulated walls; and (3) the loose parenchyma of star-shaped cells *S* that makes up most of the tissue of the hilum.

The Embryo.—If the seed be soaked, the seed coat may easily be removed from the germ or *embryo* (Fig. 53). This consists mostly of two thick *cotyledons* or seed-leaves. If these be separated there remains clinging to one cotyledon, the remainder of the young plantlet consisting of the cylindrical *hypocotyl*, *W*. whose root end is at the micropyle. At the other end is the primary leaf bud or *plumule*, *B*. of which the two other leaves are evident.

In germination the hypocotyl elongates, the free end forming the primary root, while the other end makes the portion of the stem which pushes the cotyledons into the air. The subsequent growth of the stem proceeds from the plumule.

Microscopic Structure of the Cotyledons.—The two cotyledons make up the greater part of the embryo. The epidermis of both surfaces consists of small approximately cubical cells filled with grains of aleurone. The majority of the cells of the cotyledons are palisade in form, thin walled, and filled with aleurone and oil though in some varieties starch is present (Fig. 54). The aleurone grains are spherical or polyhedral in form, and between them is the oil. In many of the cells occur crystals of calcium oxalate.

Identification of Soybean Meal.—The microscopic structure as well as the substances which comprise the soybean make it a simple matter to identify many commercial products of the soybean (Fig. 55).

Microscopically the long hour-glass or I-shaped cells are very characteristic. Also the presence of the aleurone cells in the seed coat is highly characteristic. The absence of starch indicates the soybean with certainty, but in many varieties of soybeans starch is present in small quantity.

Differences in Structure of the Seed of Varieties.—In a series of cooking tests with about three hundred varieties, the junior author found considerable variation in the amount of water absorbed by the seeds of different varieties and in the texture of the beans after cooking as shown in Table LXXXIII:

TABLE LXXXIII.—VARIATIONS IN THE COOKING QUALITIES OF SEED OF DIFFERENT VARIETIES OF SOYBEANS[1]

Variety	Weight of 100 beans (dry), gm.	Weight of 100 beans after soaking, gm.	Amount of water taken up by 100 beans, gm.	Texture of beans after cooking
Tokio	20.95	49.75	28.80	Medium
Chiquita	11.50	23.85	12.35	Medium hard
Midwest	13.48	31.12	17.64	Soft
Manchu	17.35	40.00	22.65	Medium soft
Haberlandt	19.63	45.85	26.22	Soft
Ito San	15.85	36.85	21.00	Medium
Mammoth	18.90	43.70	24.80	Hard
Easycook	22.15	53.62	31.47	Very soft
Hahto	35.95	92.80	56.85	Very soft
37264	35.95	86.70	50.75	Soft
37305	27.00	61.80	34.80	Very soft
37036	11.20	24.50	13.30	Hard
37045	21.18	50.85	29.67	Hard
37046	10.82	25.12	14.30	Soft
37055	12.57	30.00	17.43	Hard
37254	16.90	36.20	19.80	Medium soft
37259	6.60	15.90	9.30	Soft
37288	32.07	75.10	43.03	Soft

Studies of the structure of the seed of several of these varieties by Dr. Albert Mann, of the United States Department of Agriculture, showed that there was an appreciable difference in the structure of the Easycook and other varieties. The most important difference was the much greater permeability of the skin or integument of the Easycook variety. This permeability is due to a very great looseness in the cells comprising the various layers of the integument; particularly so of the outer or palisade layer. The walls of all the cells of the integument are more delicate and, therefore, more permeable than those of the Mammoth Yellow, which does not cook up easily. The palisade cells on account of their external position doubtless play the most conspicuous part in this particular. It was noted that the looseness in cell structure and thinness of cell walls were equally pronounced in the tissue of the cotyledons.

It would seem that varieties suitable for easy cooking might be

[1] One hundred seeds of each variety were used. The seeds were weighed dry then after soaking for 17 hr. weighed again. Each sample was cooked for a period of 2 hr.

selected by such comparison in structure of seed. However, it will be noted in Table LXXXIII that the amount of water absorbed does not always indicate an easily cooked seed. In general, those varieties absorbing a large amount of water cooked rather easily, but in a very few instances varieties absorbing small amounts of water cooked quite easily. It was found that in addition to difference in structure, the varieties as the Easycook, Hahto and Tokio contained more starch, which was scattered more or less through the cotyledons.

CHAPTER XI

SOYBEAN OIL

In Manchuria, soybeans are grown largely for oil, which is one of the most important commercial products of this plant. In Asiatic countries the oil is used largely for food and in the manufacture of food stuffs, paints, waterproof goods, soaps, printing inks, and for lubricating and lighting. Since about 1908 large quantities of oil and of beans for the production of oil have been imported by America and Europe, where it is utilized for various industrial purposes, principally in the manufacture of soap and paints. However, considerable quantities are used in the manufacture of lard and butter substitutes, salad oils, and in the manufacture of rubber substitutes and waterproof goods. Soybean oil has an important place in the world's trade and commercial utilization of vegetable oils.

Soybean Oil.—The oil extracted from the soybean belongs to the semi-drying class of oils; that is, those having properties intermediate between drying oils, such as linseed oil, and non-drying oils, such as olive oil. However, considerable variation occurs in its drying qualities as well as in its color, odor and taste, depending upon the source and variety of the bean, upon the care exercised in packing and transportation of both the beans and the oil, and upon the oil-processing method. In some respects it resembles cottonseed oil, but is of a more pronounced drying character and more closely resembles in its physical properties, linseed oil. Crude soybean oil is yellow to dark brown in color and has a faint odor, somewhat "beany," but is rather palatable. For food purposes, soybean oil is refined and deodorized, the product being a neutral bland oil closely resembling edible cottonseed oil, light yellow in color, and nearly odorless and tasteless. The value and uses of the soybean oil were little appreciated in Europe or America until about 1908, when, due to the scarcity of the cottonseed and linseed supplies, soap, glycerine and paint manufacturers began to turn their attention to its possibilities. As an oil to replace linseed oil

wholly or in part, soybean oil has been found to have the widest range of substitution. With the rapid growth of the soybean industry many new trade uses have been found for the oil, and on account of its lower cost has become an important competitor of other vegetable oils.

Methods of Oil Extraction.—The introduction of the soybean into the western world for oil purposes has not made any changes

FIG. 56. An old style Chinese bean oil press, Manchuria.

necessary in the equipment of the modern oil mill. The methods employed in the extraction of oil from the soybean are similar to those for other oil seeds, such as cottonseed and linseed. In Manchuria the manufacture of oil and cake is not wholly confined to large oil centers as every small center of bean production has its native mill. Until about 1917, when the increased demand for soybean oil stimulated the installation of more modern machinery, the prevailing methods in the Orient for obtaining the oil from the beans were crude (Fig. 56). However, at the present time in the large oil centers as Dairen, Kobe and Newchwang (Fig. 57) the most modern machinery is now generally used. The extraction method is but little employed in either Japan or

Manchuria, this method being favored in Europe, particularly in England. About 95 per cent. or even more of the oil produced in Manchuria, Japan and China is obtained by expression. At Dairen and Kobe hydraulic presses similar to those in use by the American cottonseed mills have largely displaced the old hand-power presses. Two mills using the extraction process are operating in the Orient, one near Kobe and another in Dairen.

FIG. 57.—Coolies at Newchwang, Manchuria, engaged in carrying loads of soybeans from the junks to big stacks, where they are kept until the factory needs them for oil manufacture. (*Photographed by F. N. Meyer.*)

Manchurian Methods of Oil Extraction.—The method of extracting the oil from the beans in the native Manchurian mills (Fig. 56) is decidedly primitive and involves four processes: Crushing, steaming, preparing for the press, and pressing, the same also being followed in the modern oil mills. The beans are first crushed into wafers beneath a large granite millstone and then are placed in gunny bags over a wooden grating, which is laid upon pots of boiling water, being steamed in this manner for about 15 min. The resultant mass is spread out in circular frames, about 6 in. deep. Five of these frames are placed one above another in a vertical press, consisting of four uprights, with cross-beams at the top and bottom. Pressure is applied by means of wedges driven in between the cross-beams and beams placed on top of the frames, and the oil is thus expressed. When taken out, the cakes have their rims pared even with a semi-circular cutter. The percentage of oil is said to depend largely

upon the respective prices for each, being regulated by using different varieties of beans. When oil production is more profitable, yellow varieties are used, but when cake is required, green or black sorts are mixed with the yellow varieties or used alone. The large oil mills equipped with modern machinery are able to extract considerably more oil than the primitive mills. In these large mills from 50 to 75 per cent. of the oil is extracted. Only a relatively small amount of oil produced by the small native mills enters into international trade.

The amount of moisture in the beans appears to be a matter of importance in Manchuria, not only for the dealer shipping the beans, but also for the mill owner. It has been estimated that 48 lb. of the 1913–14 Manchurian crop yielded 4.7 lb. of oil while only 4.1 lb. could be expressed from the same quantity of the 1914–15.

Solvent Method of Oil Extraction.—The solvent method of extraction, involving the use of benzine or gasoline, is used by many of the large oil mills in European countries, especially England. The beans are first crushed finely and then treated directly by the fat solvent. The oil is taken out of the fat solvent by evaporating the latter, which is distilled and used over again. The residue is well dried and as a bean meal rather than cake is obtained, can be used without further treatment as fertilizer and also as a feedstuff where no prejudice exists against the use of chemically-treated beans. The chemical process can not be utilized when an edible oil is desired, as the solvent gives the oil an odor which can not be entirely removed.

It is contended that by the solvent process more oil of a better quality is extracted from the beans and the resultant meal is better suited for flour or fertilizer, as it contains less oil. When the extraction process is used about 95 per cent. of the oil is obtained, the meal containing only about 1.5 per cent. oil and 43 to 45 per cent. protein. One of the solvent process mills recently erected in Manchuria has a maximum capacity of 80 tons of beans every 24 hours. However, only 50 tons of beans are crushed daily, producing about 7 tons of oil and 40 tons of meal, the 3 tons which were lost consisting of moisture, dust and trash.

American Oil Mills.—The oil mills in the United States employ two methods of oil extraction—the hydraulic and expeller processes. Extensive tests with domestic grown beans indicate

that 1 ton of beans will yield by the expeller process an average of 32 gallons (about 7.5 lb. to the gallon) of oil and 1,600 lb. of cake, the difference (about 130 lb.) representing the loss due to cleaning and the evaporation of moisture driven off after the beans have been crushed and heated. The cost of producing oil and cake by either process is said to be less with the soybean than with cottonseed. The cotton oil mills can easily handle soybeans with little or no change in their present equipment. As soybeans may be stored with less danger of deterioration than cottonseed, it is practicable to press the beans after the regular cottonseed crushing season is over.

Methods of Shipping and Marketing Soybean Oil.—Soybean oil shipped from Oriental ports is usually packed in cases containing two 5-gal. tin cans each. The cans are usually second or third hand when ready for export, having been used previously as containers for illuminating oils. As a result of their poor condition, the cans usually develop leaks during the ocean voyage, which accounts for a loss estimated at 5 per cent. of the oil between the mill and the consumer. No other method of shipment has yet been used on an extensive scale. The use of barrels or drums has been restricted by the high additional freight rates on the containers, which must be returned empty to the Orient, and by the high original cost of such containers, Undoubtedly the best method of shipment is in tank steamers. although facilities are said to be lacking in the Orient for loading tank steamers.

In the United States, soybean oil has been handled in barrels and in tank cars. The large shipments of imported oil from the Pacific ports has been handled largely in tank cars. In fact soybean oil may be handled in the same manner as cottonseed oil and other vegetable oils.

In the Orient there are three classes of wholesale dealers in the domestic oil trade in producing centers,—original importers with agents at the main mill centers, wholesalers acting either as agents of the above or representing mills direct, and retailers dealing with the trade. Oil is retailed for cash. Oil is sold to customers in brass containers made to hold the required weight. Adulteration and underweight are often practiced, but by dealing with certain reliable distributors it is possible to secure honest weight and pure oil at a slightly advanced price.

Soybean oil is generally handled between Chinese ports in

containers weighing three piculs (picul = 133 lb.). Oil for domestic consumption, is a regular item of import from Manchuria mill centers, and the price is advanced in winter when most of the northern ports are icebound. Oil is sold wholesale to retailers on 20 days' credit, but wholesalers deal with importers on a cash basis. Wholesalers are in reality a compact organization of brokers who are under moral and customary obligation to dispose of all the stocks of the importers, and while they deal with the importers on a cash basis they really work on a stated commission. Immediate and future (forward) transactions are made, and in the case of the latter 30 per cent. deposit is required. Regular oil exchanges are held in the principal centers, and importers holding large stocks usually rule the market prices.

Prices of Soybean Oil.—As soybean oil is competitive with and can be substituted wholly or in part for cottonseed, coconut and linseed oils particularly, variations in price are determined largely by changes in price of the others mentioned. Only slight variations occurred between 1912 and 1915, the prices ranging from $5\frac{1}{4}$ to $7\frac{1}{4}$ cts. per pound. Early in 1916 prices started rising until soybean oil was quoted at $19\frac{3}{4}$ cts. per pound the latter part of 1918. In 1913 soybean oil quotations were about 6 cts. per pound below those of coconut oil, but at the present time soybean oil is practically on a par with coconut oil. Oil dealers state that soybean oil must sell at from 2 to 3 cts. below linseed oil to find general use in the paint, varnish and similar industries. Cottonseed and linseed oils in reality determine oil prices in the edible and industrial field, respectively. Extracted soybean oil is generally quoted at from $\frac{1}{4}$ to $\frac{1}{2}$ ct. per pound less than the expressed oil.

In lard compounds, prices will largely determine which oil is to be used. As an edible or table oil, peanut oil and in a lesser degree cottonseed oil are generally considered superior to soybean oil. In paints, varnishes and linoleums, at the present linseed oil price and supply, soybean oil may be actually indispensable. Soybean oil has nearly displaced linseed oil as a soft-soap material, and with the use of the hydrogenation process can serve in the manufacture of hard soaps in which it now enters in equal quantities with linseed oil. Although cottonseed oil is at present preeminent in lard compounds and substitutes, the hydrogenating process by producing a practically tasteless and odorless product, will tend to make the choice between the various oils

depend on the prices rather than on any inherent characteristics of the oils. Methods of refining and deodorization as well as the hardening processes are tending to equalize oil prices.

Utilization of Soybean Oil in Soap Manufacture.—Soybean oil was at first used in Europe and America in its crude state principally in the manufacture of soft soaps. As a soft soap material it has practically displaced linseed oil, and with the use of the hydrogenation process can serve in the manufacture of hard soaps in which it now enters in equal quantities with cottonseed oil. The soap industry has been the largest single consumer of crude soybean oil. The quantity used increased from 1,182,000 lb. in 1912 to 124,058,000 in 1917, in which year it was practically on a par with cottonseed oil as a soap-making material and represented 24 per cent. of the total vegetable oils used in that industry. The following table shows the consumption of vegetable oils by the soap industry in the United States.

Table LXXXIV.—Consumption of Vegetable Oils by the Soap Industry in the United States

Products consumed	1912, lb.	1914, lb.	1916, lb.	1917, lb.
Coconut oil	78,816,000	77,959,000	111,084,000	168,602,000
Corn oil	9,822,000	11,368,000	12,821,000	15,997,000
Cottonseed oil	132,312,000	119,254,000	194,916,000	126,390,000
Linseed oil	1,390,000	1,034,000	803,000	1,006,000
Palm oil	7,546,000	71,896,000	14,938,000	27,345,000
Palm-kernel oil	20,579,000	31,376,000	5,804,000	4,762,000
Peanut oil	31,000	76,000	1,181,000	15,126,000
Soybean oil	1,182,000	4,499,000	57,373,000	124,058,000

Soybean oil has been found especially suitable for the soap maker's purpose on account of its low content of free fatty acids and unsaponifiable matter. In the latter respect it has proved superior to any of the other oils or fats of commerce, whether of vegetable or animal origin. When properly refined, soybean oil will yield about 10 per cent. glycerine as a by-product in the manufacture of soaps. This glycerine has been found to be equal in value to that recovered from other soap-making fats such as tallow, cottonseed oil, coconut oil, etc. It is subsequently distilled for explosives such as dynamite, cordite, blasting gelatine, and for purposes in the arts.

Soybean Oil for Food.—One of the principal uses of soybean oil in Asiatic countries, chiefly China, is for food, it being consumed largely in the crude state by the poorer classes, but among the rich it is boiled and allowed to stand until clarified. Before the oil can be used in food products it must be refined and deodorized. The refining process invariably aims at the production of an edible product for use as a salad or cooking oil (usually blended with other oils) and for use in lard and butter substitutes. In the latter two products the oil is often first hydrogenated. This method of hardening tends to reduce the advantages that some oils formerly held over others. Deodorization is practically complete in hydrogenation. The product, therefore, made from cottonseed oil has no intrinsic superiority over that made from soybean oil. The improved methods of deodorizing and bleaching soybean oil have tended to remove a former prejudice against its use as a table oil. Several firms in Europe and America are packing soybean oil for sale to the retail trade, and it is claimed that a satisfactory market has been found. The following table shows the consumption of vegetable oils in the United States in the production of lard and butter substitutes.

TABLE LXXXV.—CONSUMPTION OF VEGETABLE OILS IN THE PRODUCTION OF LARD SUBSTITUTES AND OLEOMARGARINE IN THE UNITED STATES

	Cottonseed, lb.	Coconut, lb.	Corn, lb.	Soybean, lb.	Peanut, lb.
Oleomargarine					
1912	17,837,000	293,000	....	708,000	2,453,000
1914	21,205,000	112,000	....	486,000	3,137,000
1916	49,960,000	563,000	147,000	2,123,000	5,335,000
1917	63,652,000	19,763,000	859,000	6,614,000	10,498,000
1918	36,454,000	61,773,000	60,000	5,921,000	21,593,000
Lard Substitutes					
1912	866,696,000	....	....	....	1,687,000
1914	1,053,142,000	....	....	1,585,000	2,144,000
1916	919,447,000	....	13,105,000	14,247,000	17,869,000
1917	1,060,214,000	5,545,000	4,166,000	34,351,000	12,209,000
1918	1,015,051,000	13,408,000	2,288,000	56,517,000	27,912,000

Soybean oil has been studied with other oils in a series of experiments carried on by the Office of Home Economics of the U. S. Department of Agriculture and found to compare favor-

ably with the more common culinary table oils with respect to the thoroughness with which it is assimilated. The digestibility of soybean oil for man was studied by Korentschewski and Zimmerman (1905). The coefficient of digestibility was found to be about 95 per cent.

Use in Paint Manufacture.—In the search by manufacturers for new oils to replace linseed oil partly or wholly, soybean oil was found most suitable. In Europe and America, paint grinders are using large quantities of this oil in the manufacture of certain types of paint. Gardner (1914) has conducted extensive tests with soybean oil comparing it with linseed and other oils in different proportions. On account of the inferior drying qualities of soybean oil as compared with linseed oil, it cannot entirely displace the latter, and its use in connection with linseed oil will be limited to from 25 to 50 per cent., depending on the product in which it is used. It is claimed that no inferior qualities are developed in the paints if the proportion of soybean oil to the total oils does not exceed the amounts mentioned. Soybean oil is not really competitive with linseed oil, but seems rather, at the present linseed price and supply, a necessary adjunct to it.

Miscellaneous Uses.—The immediate value of a vegetable oil, such as soybean oil, for candle making is determined by the relative proportions of solid and liquid acids, the former being represented by stearic and palmitic, and the latter by oleic and linolic acids. In the case of soybean oil, the large proportion of liquid fatty acids, about 80 per cent, as compared with 11.5 per cent. of stearic acid, indicates its employment for edible purposes or soap-making rather than for the manufacture of candles.

The problem of producing an artificial rubber is said to have been solved by two German scientists, using soybean oil as a raw material. The oil is converted into a glutinous viscid product by nitric acid. This mass is thereupon treated with diluted alkalies, and then heated to a temperature of 150°, thereby changing it to a tough and yet elastic body, resembling rubber, which by mechanical handling can be given any shape and like the natural caoutchouc can be vulcanized by the customary processes. It remains to be seen whether or not this invention merits its claim of producing a substitute for natural rubber cheaper than the latter. At the present time soybean oil is used to some extent in the manufacture of various rubber substitutes.

As a lubricant, soybean oil is used to a very considerable

extent in north China and Manchuria for greasing axles and parts of native machinery. In south China large quantities of oil are used in the manufacture of water-proof goods, and it is also mixed with lacquer for varnish and printing ink. The oil is also used in the Orient in the manufacture of various foodstuffs, paints, soaps, and for lighting.

Other trade uses of this oil are the manufacture of linoleum, waterproof liquid, toilet powder, enamels and waterproof goods, such as cloth, umbrellas and lanterns.

CHAPTER XII

SOYBEAN CAKE OR MEAL

The cake or meal remaining after the oil is extracted is a most valuable product and has the widest usefulness. The yellow-seeded varieties produce a bright yellow meal, while that from the brown and black varieties is of a darker shade. The cake or meal from which the oil has been extracted by means of the solvent process is of the brighter color than that from which the oil was removed by heating and pressure. Soybean cake or meal when fresh has a sweet, nutty flavor, and not at all unpleasant to taste. As a feed, soybean meal is highly concentrated and nutritious and is relished by all kinds of live stock. In the Orient it is used to a very considerable extent for fertilizing purposes. The use of the meal as flour for human food has become important in several European countries during the last few years and to some extent it is used in America.

Feeding Value.—In Manchuria soybean cake or meal, mixed with bean and kaoliang (sorghum) stalks, is used as feed for horses and mules, but only when very hard work is done. It is also recognized in Japan as a valuable feed for work animals and as a fattening feed for animals not employed in farm work.

Soybean cake ground into meal is used almost entirely for feeding purposes in European countries and America. Practical experience supplemented by carefully conducted experiments, indicates the high-feeding value of this meal for all kinds of farm stock. The low price of the meal in comparison with other concentrated feeds has also made it very popular, especially in the dairy countries of Europe. Some hesitation was shown in Europe when the meal was first introduced, as it was feared that the taste of the butter and other milk products might be affected by feeding the meal to cows. However, experiments proved the fear groundless and the demand for the meal has steadily increased.

The use of the meal in America thus far has been confined almost entirely to the Pacific Coast states. It is considered a valuable feed not only by dairymen, but also by poultrymen. The meal has been used to some extent by kennel owners who have found it to be a highly satisfactory dog feed.

Composition.—The analyses of soybean cake or meal, as shown in the following table, would indicate that as a stock feed it compares very favorably with similar concentrated feeds.

TABLE LXXXVI.—COMPOSITION OF SOYBEAN CAKE, MEAL, AND OTHER IMPORTANT OIL FEEDS. COMPILED FROM VARIOUS SOURCES

Kind of feed	Constituents, per cent.					
	Moisture	Protein	Fat	Nitrogen-free extract	Ash	Fiber
Soybean meal (U. S.)	7.59	44.65	8.77	27.12	5.89	5.96
Soybean cake (China)	17.37	44.00	7.00	21.12	5.52	4.98
Soybean cake (Manchuria)	15.60	41.37	8.60	24.81	5.25	4.37
Soybean cake	11.11	43.29	6.10	34.04	5.46	
Soybean cake	10.07	40.56	5.04	30.89	6.59	6.95
Soybean cake	11.33	42.69	5.95	28.07	5.94	6.02
Soybean cake	10.30	42.43	6.33	29.34	5.90	5.40
Soybean meal	11.52	46.74	2.20[1]	28.65	6.75	4.14
Soybean cake	11.23	43.58	5.13	30.10	6.38	3.58
Soybean cake	12.90	40.80	7.90	28.10	4.90	5.40
Soybean meal (fine)	10.41	41.07	2.15[1]	28.55	5.50	12.32
Soybean meal (coarse)	8.98	41.50	2.17[1]	33.71	5.77	7.87
Soybean cake	12.87	44.90	1.33[1]	30.90	5.42	4.30
Soybean cake	12.10	42.20	7.25	29.05	5.10	4.30
Cotton seed	6.62	40.29	7.41	28.63	6.21	10.84
Linseed (old process)	8.98	33.23	7.20	36.51	5.40	8.68
Linseed (new process)	9.63	37.51	2.49	36.09	5.54	8.74
Peanut (decorticated)	10.73	46.84	7.91	24.34	4.89	5.29
Sunflower seed	7.68	23.80	7.94	27.49	5.09	28.06

Soybean Cake or Meal for Dairy Cows.—Rather extensive feeding experiments were conducted under the direction of Hofmann-Bang (1911) at the Copenhagen Experiment Station to determine the feeding value of soybean cake for milch cows. It was found that 2.2 lb. of soybean cake fully replaced the same amount of other high protein cakes fed (cottonseed meal, peanut and sunflower-seed cakes) without affecting the milk production, the condition of the cows or the chemical composition of the milk. When good, fresh soybean cakes were fed, no deleterious influence from feeding the cakes, even when these were fed excessively, was traceable in the flavor or odor of the butter.

Gilchrist (1909) at the Armstrong College, England, conducted experiments testing the comparative feeding value of soybean

[1] Oil extracted by solvent process.

cake and decorticated cottonseed cake. As regards milk production, there was a slight advantage in favor of the soybean cake, but it was so small that the two cakes were considered to be equal in this respect. Both feeds also gave similar results relative to the fat content of the milk. The cows, however, gained rather more in weight while they were receiving the soybean cake than they did on the decorticated cottonseed cake.

An experiment similar to the preceding one was carried on at the Royal Agricultural College, England. The yield of milk appeared to be little affected by the kind of cake used. The percentage of butter fat in the case of the bean cake remained almost constant, a slight increase, if anything, being noticed; with the decorticated cottonseed cake the percentage of butter fat had a tendency to fall. The butter produced by the bean cake was of a soft oily nature and churned quickly, but it yielded well. It was, however, of a decidedly paler color and somewhat inferior in flavor as compared with that from cottonseed cake. The butter produced by the decorticated cottonseed cake was hard and took a longer time to churn and the yield was not so good as with the bean cake. No difference in laxative effect or otherwise was observed between the two cakes.

Ott de Vries (1909) in Holland made a comparison of soybean cake and linseed cake rations on the yield of milk and the properties of butter and cheese. During the main feeding period the average production of milk was practically equal with the two cakes, but in the average production of butter fat the linseed cake gave larger returns. The refractive index of soybean butter was slightly lower and the percentage of volatile acids was slightly higher than that of butter made during the linseed ration period. When scored by good judges there was no appreciable difference in the quality of the butter. The properties of cheese were unaffected. The soybean ration produced no unfavorable effect on the health of the cows, and in all respects was considered to be a valuable feed.

Feeding experiments were conducted by Lindsey, *et al.* (1909) of the Massachusetts (Hatch) Experiment Station to ascertain the effect of soybean meal with a minimum percentage of oil upon the composition of milk and butter fat, and upon the consistency or body of butter. The results obtained show that the meal with the oil partially extracted seemed to be without influence in changing the proportions of the several milk constituents

or in imparting any flavor to the milk. The meal did not modify the chemical character of the butter fat nor did it have any effect upon the production of butter. However, a noticeable softness was imparted to the body of the butter but not sufficiently so as to injure its commercial value except during the warm months. At the same station Brooks (1903) in an earlier experiment, comparing soybean and cottonseed meals, reports that from the soybean meal somewhat more milk was obtained, less but richer cream, and butter of a better quality than from cottonseed meal. With cottonseed meal the butter was harder but had a greasy, though firmer texture. The soybean butter was of a higher color and much more agreeable texture and flavor.

At the Tennessee Experiment Station, Price (1908) in testing home-grown rations in the economical production of milk and butter found that the yields both of milk and butter were about 5 per cent. greater for soybean meal in comparison with cottonseed meal. Otis (1904) at the Kansas Experiment Station found that when soybeans formed one-half of the concentrates of the ration soft butter was produced. Rosengren (1910) in a study of the influence of soybean cake on the quality of butter found that soybean cake fed to milk cows at the rate of 5.5 lb. per head a day did not cause any undesirable flavors in the milk or butter.

Soybean Cake or Meal for Cattle.—Feeding experiments comparing soybean cake and linseed cake for fattening were carried out by Bruce (1909) of the Edinburgh and East of Scotland College of Agriculture. The results obtained indicated that soybean cake, when used as a supplement to feeding stuffs in bullock fattening to the extent of from 4 to 5 lb. daily is a healthful cattle feed and a satisfactory beef producer, but weight for weight, is not equal to linseed cake.

In other experiments carried on in England by Gilchrist (1912) comparing decorticated cottonseed cake and soybean cake as concentrates for young cattle, the cottonseed cake caused slightly faster gains than soybean cake, but in one experiment was less economical. It was also found that when a larger proportion of protein was fed than called for by the Wolff-Lehmann standard, somewhat faster gains were made but at less profit.

The actual feeding value of ground soybeans as a substitute for cottonseed meal in rations for fattening cattle has been tested by Skinner and King (1913, 1914 and 1915) and King (1920) at the Indiana Experiment Station in a series of three trials with

two and three-year-old cattle fed shelled corn, corn silage, and cured roughage. Two similar lots of cattle were fed the same ration, except that one lot received cottonseed meal and the other lot ground soybeans as supplements to the ration. The supplement was fed at the rate of 2.5 lb. daily per 1,000 lb. live weight.

The results show a larger feed consumption where cottonseed meal was fed then where ground soybeans were used. This difference was due to the fact that the cattle fed soybeans had unsteady appetites during the latter part of the feeding periods. As long as they were palatable they are as efficient as cottonseed meal as a supplement to rations for fattening cattle. Their palatability may be limited to one hundred days feeding. After the beans are no longer relished by cattle, they are less efficient than cottonseed meal. The marked laxative effect of soybeans is also objectionable. This effect of the soybeans was doubtless due to the large percentage of fat contained therein. The cost of gain was slightly in favor of the soybeans with beans valued at the same price per ton as cottonseed meal. All factors considered the profit per head was slightly greater in the lot receiving ground soybeans as supplement to the ration, if soybeans are valued at the same price as cottonseed meal.

Soybean Cake or Meal for Swine.—Extensive experimental work has been conducted by Gray (1917) at the North Carolina Station to determine the feeding value of soybean meal when fed to hogs. The results indicate that both for rapidity and economy of gains this meal has proven itself as a superior product for part of the ration for hogs. The question of soybean meal producing soft pork was also tested out by this station. At the beginning of the test, the average melting point of the fat was found to be 41.4 degrees, being almost as firm as fat taken from hogs fattened on a ration of corn alone. With hogs fed on a ration of two-thirds cracked corn plus one-third soybean meal the melting point of the fat was found to be 42.0 degrees. The firmest bodies were found in the lots where soybean meal was fed. The conclusion reached was that the results so far secured seem to indicate that soybean meal does not produce soft-bodied hogs.

In a preliminary experiment at the North Carolina Experiment Station by Gray (1916) as to the relative value of wheat shorts, soybean meal and peanut meal as supplements for corn, pigs averaging about 43 lb. each were fed for 140 days in very small cement floored lots. The pigs fed corn and shorts (2:1) gained an average of 0.29 lb. per head per day at a cost of 19.8 cts. per

pound of gain. Those fed corn and soybean meal (2:1) gained 0.44 lb. at a cost of 11.79 cts., and those fed corn and peanut meal (2:1) gained 0.37 lb. at a cost of 14.56 cts. In this test corn was valued at one dollar per bushel, soybean meal at $40.00 a ton and peanut meal at $30.00 a ton.

At the Wisconsin Agricultural Experiment Station, Humphrey and Fuller (1904, 1905, 1906) compared soybean meal and wheat middlings for pork production in three separate experiments in as many years. Two-thirds of the grain ration was corn meal in each case. In each of the experiments the largest gains were made on the soybean rations. Soybeans proved about 10 per cent. superior to wheat middlings for pork production, figuring the cost of the feeds as the same.

At the Kansas Agricultural Experiment Station, Cottrell, *et al.* (1900) have several times tested the value of soybean meal in combination with corn meal and with kafir meal in comparison with the two latter feeds alone in feeding hogs. The feeds were mixed in the proportion of four-fifths corn or kafir and one-fifth soybeans. Larger gains, varying from 13 to 37 per cent. were made in every case on the mixed rations than on corn or kafir alone. With corn meal alone 100 lb. of gain cost $3.92, with corn meal and soybean meal $3.73, and with kafir meal and soybean meal $3.37. For these computations the value of corn meal was fixed at $14.00 a ton, kafir meal at $13.00 a ton, and soybean meal at $25.00 a ton.

An experiment was carried on by Wheeler, *et al.* (1913) at the Kansas Agricultural Experiment Station to compare tankage and soybean meal as supplements to corn for fattening hogs. Although the average daily gain was less with soybean meal and the cost of feed per 100 lb. of gain greater than with the tankage ration, the value of soybeans as a hog feed was demonstrated to be far superior to corn meal alone.

At the Indiana Agricultural Experiment Station, Skinner (1905) compared rations of two parts of corn meal and one part of soybean meal with corn meal and wheat middlings in equal proportions and with five parts of corn meal and one part of tankage for pork production. The soybean ration produced the largest daily gains and this with the smallest quantity of feed consumed for each pound of gain. Further experiments by Skinner and Cochel (1908) conducted at this station showed the value of soybean meal for fattening hogs as compared with linseed meal, tankage and other feeds. The feeding of soybean

meal in connection with corn resulted in a more rapid gain at less cost of feed than with linseed meal. It was found that the cost per 100 lb. of gain was \$3.82 with linseed meal, while with soybean meal, the cost was \$3.46.

Recent feeding experiments with swine by Vestal (1922) at the Indiana Experiment Station indicate that the addition of a mineral mixture to corn and soybean rations greatly increased the rate and economy of gains. It was found that corn and soybeans without minerals ranked considerably below corn and tankage in the production of rapid and economical gains. Corn and soybeans with wood ashes 10 parts, 16 per cent. acid phosphate 10 parts and commercial salt one part by weight ranked slightly above corn and tankage in rate and economy of gains, and gave the best results of any of the mineral supplements with corn and soybeans. This ration and mixture increased the rate of gain 30 per cent. and decreased the feed requirement 13 per cent. A mixture consisting of 10 parts limestone, 10 parts 16 per cent. acid phosphate and 1 part common salt, ranked next to the preceding mineral mixture as a supplement to soybeans and corn. It was found that the minerals used in the feeding trials improved the appetites of the hogs as indicated by an increase in feed consumption in every case.

Haselhoff (1912) in Germany, found in fattening experiments with hogs that soybean meal was somewhat cheaper than barley meal when given with a variety of other feeds. Studies of the fat showed that soybean meal had no great effect on the index of refraction, saponification number or iodin number.

At the Kentucky Experiment Station, Good and Mann (1918) conducted an experiment comparing velvet-bean meal, tankage and soybean meal as supplements to corn meal in feeding hogs. A lot of eight Duroc-Jersey and Berkshire shotes each weighing originally 125 lb. was fed on corn meal and velvet-bean and hull meal (5:1) another on corn meal and tankage (9.1) and a third on corn meal and soybean meal (7.1) for 89 days. The average gains were respectively 0.8, 1.52 and 1.42 lb. per pig and the corresponding amounts of feed consumed per pound of gain were 6.5, 4.2 and 4.5 lb. Although the velvet-bean meal was much cheaper than tankage or soybean meal, the animals getting velvet-bean meal were fed at a distinct loss. The value of soybeans as a supplement to corn is pointed out.

Hays (1919), at the Delaware Experiment Station, carried on

a series of tests with regard to the relative efficiencies of tankage, linseed meal, soybean meal, gluten feed and coconut oil meal for growing fattening hogs. In the average daily gain and the total gain per pig, the coconut oil meal gave the largest returns and was followed by soybean meal. However, the total feed cost per 100 lb. of gain was lowest with soybean meal.

Feeding trials involving comparisons between soybean meal and other protein concentrates as supplements to corn for fattening hogs are reported by Robison (1920) of the Ohio Experiment Station. The results of two 17-week comparisons of soybean meal with other supplements for fattening pigs are shown in the following table.

Table LXXXVII.—Two 17-Week Comparisons of Soybean Meal with Other Supplement for Fattening Pigs

Feeds offered	Average initial weight, lb.	Daily concentrate ration,[1] lb.	Daily gain per head, lb.	Consumed per pound of gain		Cost of 1 lb. gain, cts.	Returns on feed per day per head, cts.
				Corn, lb.	Supplement, lb.		
In dry lot:							
corn	66.8	3.05	0.50	5.86	....	16.1	−0.56
corn, linseed meal (6 to 1)	66.5	3.31	1.11	3.40	0.57	11.6	−3.75
corn, soybean oil meal (9 to 1)	67.7	3.30	1.27	3.35	0.37	10.9	5.21
On rape pasture:							
corn	67.3	3.48	1.12	4.26	....	11.7	3.71
corn, tankage (19 to 1)	66.6	3.71	1.51	3.65	0.19	11.1	5.90
corn, soybean oil meal (12 to 1)	67.7	3.79	1.60	3.56	0.30	11.1	6.21
corn, ground soybeans (8 to 1)	67.5	3.83	1.38	3.70	0.46	12.0	4.11

The poor showing of ground soybeans in comparison with soybean meal is confirmed by a previous feeding test. Apparently the ground beans are not as palatable as the soybean meal.

Soybean Cake or Meal for Sheep.—The University College of North Wales conducted a feeding experiment, involving the use of soybean cake and linseed cake with sheep. Although the net gain was in favor of the linseed cake, the experiment showed that soybean meal is a good feeding stuff for sheep.

At the Wisconsin Experiment Station the value of soybean seed was tested for fattening lambs by Richards and Kleinheinz (1904). In one experiment two lots of 10 lambs each were fed

[1] Per 100 lb. live weight.

on the same roughage. One lot received shelled corn, and whole soybeans in equal proportions, while the other received the same quantities of shelled corn and whole oats. The average gain of each lamb during a period of 12 weeks was 16.3 lbs. when soybeans constituted a part of the ration and but 13.7 lb. when oats were used. A pound of gain was produced on 6.11 lb. of grain and 7.11 lb. of roughage in the soybean ration, while 7.28 lb. of grain and 8.62 lb. of roughage were required on the oats ration. In another experiment the same rations were fed for 12 weeks to two lots of 9 lambs each. The lot receiving the soybean ration gained 119 lb. in weight and produced 95.1 lb. of wool, against 71 lb. increase in weight and a production of 81.3 lb. of wool for the lot receiving the oat ration. The second lot also consumed more feed per pound of gain.

Investigations have been carried on at the Indiana Experiment Station by Skinner, *et al.* (1916, 1917, 1918) in sheep feeding comparing various supplements as soybeans (ground), linseed meal and cottonseed meal. In these trials the ground soybeans did not give as satisfactory results as cottonseed meal as a supplement in the rations of fattening lambs.

Skinner and Starr (1918) found that lambs fed linseed oil meal were valued at $17.25 per hundred pounds and returned a net profit of 29 cts. per head; lambs receiving cottonseed meal were valued at $17.00 and returned a net profit of 10 cents; and the lambs fed soybeans were valued at $17.00 returned a net profit of 3 cts. per head.

Skinner and King (1917) found that lambs fed ground soybeans as supplement to shelled corn, clover hay and corn silage maintained eager appetites but failed to consume as large quantities of feed as those fed cottonseed meal as supplement to the ration. Lambs fed ground soybeans gained 35.1 lb. per head as compared to 36.5 lb. per head by those fed cottonseed meal. Lambs fed ground soybeans as supplement made gains at a cost of $9.76 per 100 lb. as compared to a cost of $9.92 per 100 lb. by those fed cottonseed meal. A profit of $3.09 per head was returned for lambs fed ground soybeans, being valued at $14.15 per hundred while the lambs fed cottonseed meal were valued at $14.25 per hundred and returned a profit of $3.18 per head.

Soybean Cake or Meal for Poultry.—In feeding trials with young chicks at the North Carolina Experiment Station, Kaupp (1917) found that when soybean meal was fed in equal quantities with wheat shorts and cracked corn mixed with sweet milk, the

soybean meal proved to be a most valuable feed and one to be recommended as a good ration for feeding little chicks. One lot of chicks on soybean meal averaged 1.4 lb. when 8 weeks old. A second lot handled and fed exactly as the first, except that rolled oats was used in place of soybean meal, averaged 1.1 lb. in weight at the same age. In all 16 lots of chicks were fed in this manner and the results were all satisfactory as to the soybean meal, and it was concluded that soybean meal can replace rolled oats in chick feeding.

Lewis and Thompson (1915) conducted feeding tests for 2 years, comparing the relative value of protein feeding stuffs from animal and vegetable sources for poultry. The birds receiving protein from an animal source, meat scrap, produced in the 2 years of the experiment 8,501 eggs as compared with 4,710 by the soybean meal pen, 4,003 by the gluten feed pen, 2,847 by the linseed meal pen, and 2,995 by the cottonseed meal pen. It will be noted that soybean meal ranked first in the order of egg production for vegetable proteins.

TABLE LXXXVIII.—GROWTH AND NITROGEN ELIMINATION OF CHICKS FED VARYING AMOUNTS OF MEAT SCRAP OR SOYBEAN MEAL OR BOTH, IN ADDITION TO A CORN RATION. (INDIANA EXPT. STA.)

Protein added to basal ration, per cent.	Protein in feed (approximate) per cent.	Individual gain per fortnight			Gain per gram of protein fed			Nitrogen in excreta[1]				Nitrogen waste above control lot, per cent.
		Meat scrap lots, gm.	Soybean lots, gm.	Mixed protein lots, gm.	Meat scrap lots, gm.	Soybean lots, gm.	Mixed protein lots, gm.	Meat scrap lots, per cent.	Soybean lots, per cent.	Mixed protein lots, per cent.	Average all lots, per cent.	
5	13	87.0	89.8	90.9	1.31	1.35	1.37	2.73	2.74	2.91	2.79	24.5
10	16	85.3	104.3	101.2	0.89	1.08	1.05	3.56	3.62	3.52	3.57	59.4
15	18	80.6	97.3	99.8	0.85	1.03	0.88	3.35	4.49	4.00	3.95	76.3
20	20	87.2	90.2	98.0	0.76	0.83	0.83	4.44	4.42	4.92	4.59	105.0
Average........	..	84.5	95.3	97.5	0.95	1.07	1.03	3.52	3.82	3.84		

[1] Average determination at the ages of 4, 8, 16 and 20 weeks.

Investigations were conducted at the Indiana Experiment Station by Philips, *et al.* (1920) as to the influence of source and proportion of protein in the feed on the growth and nitrogen metabolism of young chicks. Table LXXXVIII summarizes the results obtained.

Poultrymen in the Pacific Coast states have used soybean meal for several years and consider it a most excellent feed for growth and egg production.

Kennard, *et al.* (1922*b*) in a series of experiments found that soybean meal with a suitable salt mixture is a better supplement to corn meal than meat scraps and is nearly as good as condensed buttermilk when fed to chickens for short-time, intensive feeding periods. A simple salt mixture of bone ash, limestone and salt (60:20:20) proved as effective as more complex mixtures for supplementing rations consisting of corn meal and soybean meal. To be most effective, the amount of the salt mixture to be added appears to be about 2 per cent. of the ration, or slightly less. In an average of nine different experiments in which corn meal was supplemented by soybean meal, with and without a salt mixture, the use of the mineral supplement with a similar feed intake increased the value of the ration 38.86 per cent. Hens responded to the use of the salt mixture in a similar manner to that of the young, growing birds. It appears that the mineral deficiency of the basal ration is not such as to interfere with the storage of fat, but rather accelerates its formation at the expense of protein growth. The increase of flesh produced by the ingestion of the basal ration supplemented by the salt mixture contained 61.38 per cent. more protein than that obtained by feeding the basal ration without the salt mixture. The birds receiving the supplemented ration retained 27.38 per cent. more of the nitrogen ingested than did those receiving the basal ration alone.

In further experiments Kennard and White (1922), found that soybean meal may be successfully used as a protein supplement to rations for growth of chickens or for egg production, if a suitable mineral mixture is added. The mineral mixture increased the value of the vegetable protein ration for growth and egg production over 40 per cent. The egg production from the vegetable protein ration with mineral mixture was comparable with that of the standard meat scrap ration. The mineral mixture used for growth and egg production was bone phosphate 60 parts, salt 20 parts and limestone 20 parts.

Rock phosphate or "floats" appeared to be as effective as the bone phosphate in the mineral mixture for the growth of cockerels. The cost of the mineral mixture is nominal, being about five cents for 100 pounds of mash when the full amount or four pounds of the mineral mixture is added to each 100 pounds of mash.

Digestibility of Soybean Meal.—As regards digestibility, soybean meal compares very favorably with other oil meals, as will be noted in the following table:

TABLE LXXXIX.—COMPARISON OF THE DIGESTIBILITY OF SOYBEAN MEAL AND OTHER OIL MEALS. COMPILED FROM VARIOUS SOURCES

Kind of meal	Protein, per cent.	Fat, per cent.	Nitrogen-free extract, per cent.	Fiber, per cent.	Total digestibility, per cent	Assimilability, per cent.	Digestible albuminoids, per cent.	Starch equivalent, per cent.
Soybean (pressed)	39.2	4.4	25.6	5.5	90	96	38.4	74.7
Soybean (extracted)	41.6	1.4	27.5	7.2	97	96	40.7	73.0
Cottonseed (decorticated)	39.7	8.4	15.3	2.0	76	97	38.0	71.0
Linseed (pressed)	28.8	7.9	25.4	4.3	79	97	27.2	71.8
Linseed (extracted)	32.2	3.4	26.2	4.5	78	96	31.4	64.8
Peanut	40.0	8.3	20.0	0.8	83	98	38.7	75.7

Kellner and Newman (1893) in feeding experiments with swine in Japan computed the average digestion coefficients of fat-free soybean meal as follows: Organic matter, 90.5 per cent.; protein, 26.7 per cent.; nitrogen-free-extract, 92.4 per cent.; fiber, 60.5 per cent.

Experiments to test out the digestibility of soybean meal were carried on by the Massachusetts Experiment Station (Table XC). The test was regarded as not entirely satisfactory as the variations in the percentages of cellulose and fat digestible in the case of two sheep was too large.

TABLE XC.—DIGESTION COEFFICIENTS OF SOYBEAN MEAL OBTAINED WITH SHEEP. MASSACHUSETTS EXPERIMENT STATION

	Dry matter, per cent.	Cellulose, per cent.	Fat, per cent.	Protein, per cent.	Nitrogen-free extract, per cent.
Sheep–3	78.15	48.27	81.28	89.97	75.57
Sheep–4	85.58	94.09	90.09	92.20	77.02
Average	81.86	71.18	85.68	91.08	72.29

Injurious Effects from Soybean Meal.—Alleged injurious effects from feeding soybean cake or meal have been reported in the United States and Europe, and their cause has been the subject of careful investigation. As yet, no proof is to be had of soybean cake or meal causing any injurious effects when given to animals in reasonable quantities, and in combination with other feeds.

An experiment was carried out by the Harper Adams Agricultural College (Sawer 1911*a*) to test the question of the possibility of this cake having any detrimental effect on animals. Increasing quantities up to 7 lb. a day were given a heifer without any ill effects. Another heifer was fed on a patent cake, and then a sudden change was made to soybean cake, and in this case also no difference was observed.

A few instances are recorded in England and Scotland where cattle were claimed to have been poisoned by prussic acid in soybean meal. It was established, however, that the meal or cake was not only an excellent feeding stuff, but that it contained practically no hydrocyanic acid.

Poisonous effects resulting from the use of soybean meal from which the oil had been extracted by the solvent process led to a series of inquiries and investigations. According to conclusions reached by investigators plenty of evidence was found that soybean meal extracted with naphtha does not cause poisoning, but it appears that the trouble was caused by the use of soybean meal extracted with trichlorethylene, although this is not poisonous when given to cattle in from 1 to 3 oz. doses and for long periods. It was suggested (1) that the products from trichlorethylene by heat may be poisonous; (2) that the trichlorethylene in contact with soybean meal and heat to drive off the former may form a poison; or (3) that some of the trichlorethylene was impure and contained other bodies. It was emphasized that sheep and pigs were not affected by the meal and in the case of cattle suspicion only attaches to meal extracted with trichlorethylene, and therefore it is not advisable to use this solvent as an extractor.

Owing to its high content of protein, soybean meal should be fed with the same precautions as are observed with other highly concentrated feeds, otherwise it may give rise to digestive troubles.

Soybean Meal as Fertilizer.—The utilization of soybean meal as a fertilizer has been confined almost entirely to Asiatic countries. For centuries bean cake has been sent to the sugar plantations of southern China, and its use gradually spread to the plantations in Java and other tropical islands. The high fertil-

izing value of the cake has long been recognized by the Japanese, who import large quantities annually for use in the rice fields and as an alternative manure for mulberry trees. In Manchuria large amounts of cake are used annually on poor soils for both field and garden crops.

Although large quantities of soybean cake have been imported into the United States and Europe during the last few years, there is no mention of its use in the manufacture of commercial fertilizers. With the production in the United States of bean meal and oil from domestic-grown beans, fertilizer manufacturers became interested in the possibilities of the meal and purchased considerable quantities for this purpose.

Like cottonseed meal, soybean meal contains considerable amounts of phosphoric acid and potash, a large proportion of which is "available," but it is principally valued in fertilizers as a source of nitrogen. From the fertilizer standpoint, soybean meal is richer in plant food constituents than is cottonseed meal, and if the price is determined on the same basis as that used in calculating the fertilizing value of cottonseed meal, the soybean meal is a more valuable substance. Its composition with reference to fertilizing constituents and a comparison with cottonseed meal are shown in the following table.

Table XCI.—Fertilizing Constituents of Soybeans, Soybean Meal, and Cottonseed Meal. Compiled from Various Sources

Crop or product	Constituents, per cent.			
	Nitrogen	Ammonia	Phosphoric acid	Potash
Soybeans	6.51	7.90	1.36	1.82
Soybean cake	6.77	8.23	1.33	2.00
Soybean meal	7.24	8.79	1.44	1.85
Soybean meal	7.72	9.37	1.36	1.82
Soybean meal	7.48	....	1.40	1.83
Soybean cake[1]	7.18	8.72	2.37	2.92
Cottonseed meal	6.79	8.24	2.88	1.77

While soybean meal, as shown in the above table, has a high value as a fertilizing material, a more economical use is to feed the meal to livestock and apply the resulting manure to the soil. Feeding experiments indicate that much of the fertilizing value of feeds is recovered in the manure.

[1] Oil extracted by solvent process.

CHAPTER XIII

SOYBEAN PRODUCTS FOR HUMAN FOOD

The soybean has been utilized for many centuries by the Chinese and Japanese in the preparation of a great variety of fresh, fermented, and dried food products which form an indispensable part of their diet. The numerous food preparations of the soybean not only give flavor and relish but supply to a very considerable extent the protein that in the diet of the Western people is furnished largely by meats. Some of the soybean products are eaten at every meal and by rich and poor alike, especially in the interior of Oriental countries, where sea food is not obtainable. The soybean is seldom used by the people of the Orient for boiling or baking as is done with the field or navy bean by the Western people.

Numerous attempts have been made to introduce the soybean and its products into European countries and America for food but until recently without much success. In 1875 Professor Haberlandt (1877) of Vienna began an extensive series of experiments with the soybean and strongly urged its use as a food plant for man and animals. Although interest was increased in its cultivation during the experiments, the soybean failed to obtain any great importance in Europe until about 1909, when immense quantities of beans were imported from Manchuria for the production of oil and meal. Through the efforts of the oil manufacturers, soybean flour found favor in the manufacture of foodstuffs.

Although the soybean as an article of food has attracted attention at various times in the United States, thus far it has been but little used. For several years, a few food companies have had on the market special soybean flour prepared for persons requiring a food of low starch content. Since 1916 the dried beans have come to be used extensively in the manner of the field and navy beans. Several manufacturers have recently begun the manufacture of different foodstuffs from the soybean such as breakfast foods, crackers, baked beans, soy flour, and soy sauce.

Food Value of the Soybean.—The importance of legumes as a class is becoming more generally recognized as an economical source of protein. In view of the richness of the soybean in nutrient constituents and the extent to which these are assimilated by the body, the soybean deserves a high rank as an important food material.

The food value of the soybean in comparison with other legumes and important foods is indicated in the following table:

TABLE XCII.—ANALYSES AND CALORIES OF SOYBEANS COMPARED WITH THOSE OF OTHER LEGUMES AND FOODS. COMPILED FROM VARIOUS SOURCES

Food	Protein, per cent.	Fat, per cent.	Carbo-hydrates, per cent.	Ash, per cent.	Water, per cent.	Calories per lb.
Soybean	34.0	16.8	33.7	4.7	10.8	1,970
Navy bean	22.5	1.8	59.6	3.5	12.6	1,605
Peas	24.6	1.0	62.0	2.9	9.5	1,655
Cowpeas	21.4	1.4	60.8	3.4	13.0	1,590
Lentils	25.7	1.0	59.2	5.7	8.4	1,620
Lima bean	18.1	1.5	65.9	4.1	10.4	1,625
Frijoles (Mexican)	21.9	1.3	65.1	4.2	7.5	1,695
Peanuts	25.8	38.6	24.4	2.0	9.2	2,560
Eggs	14.8	10.5	....	1.0	73.7	720
Beefsteak	18.6	18.5	....	1.0	61.9	1,130
Pork chops	16.9	30.1	....	1.0	52.0	1,580
Cottage cheese	20.9	1.0	4.3	1.8	72.0	510
Rice	8.0	2.0	77.0	1.0	12.0	1,720
Corn	10.0	4.3	73.4	1.5	10.8	1,800
Oats	11.8	5.0	69.2	3.0	11.0	1,720
Wheat	12.2	1.7	73.7	1.8	10.6	1,750
Buckwheat	10.0	2.2	73.2	2.0	12.6	1,600
Rye	12.2	1.5	73.9	1.9	10.5	1,750

Osborne and Mendel (1917*b*) have conducted rather extensive investigations with the proteins of the soybean in comparison with other proteins. On diets containing either the soybean meal or the commercial cake as the sole source of protein used together with fats and "protein-free milk," several broods of young rats have been produced and the young grew normally on the same diet. These investigators cite this as a demonstration of the nutritive efficiency of the soybean, in striking contrast with the adverse results obtained with kidney beans and garden peas. They also state that so far as they are aware the soybean

is the only seed hitherto investigated, with the possible exceptions of flax and millet, which contains both the water-soluble and the fat-soluble unidentified dietary essentials or vitamines. This fact, taken with the high physiological value of the protein, lends a unique significance to the use of the soybean as food.

Daniels and Nichols (1917) have also investigated the nutritive value of the protein of the soybean. In a series of feeding experiments with rats it was found that animals fed rations containing 15.6 and 18.7 per cent. of protein obtained solely from the soybean have grown normally, and in the latter case have produced successive litters of young which in turn have reproduced. It is concluded that this is sufficient evidence that the protein of the soybean fulfills all physiologic requirements and appears to be quite as valuable as the casein of milk. The investigators state that these findings were somewhat surprising in view of the fact that the protein of other legumes, namely peas and white beans, has been found wanting. The above results are comparable to those obtained by Osborne and Mendel.

Digestibility of the Soybean and Its Products.—Although it is well-known that proteins and fats are essential materials in animal nutrition, recent investigations indicate that both the nutritive value and digestibility vary with proteins from different sources, and that this difference is due to the particular amino acids which they yield upon hydrolysis. The digestibility of the protein of the soybean is estimated between 65 and 92 per cent. and of the fat between 70 and 80 per cent.

Oshima (1905) in a summary of Japanese nutrition investigations gives as the average of two experiments, the coefficients of digestibility, 65 for the proteins, and 85 for the carbohydrates of the soybean. The first two experiments were made with beans simply boiled, the skins not being removed by cooking. In one experiment the quantity of beans eaten was very much larger than in the other, and the absorption was decidedly lower.

The fat of the soybean has been found to be well assimilated by human subjects. Korentchewski and Zimmerman (1905) conducted a series of experiments in which the subjects digested 95 to 100 per cent. of the oil without digestive disturbances.

In experiments with tofu, Oshima (1905) found the coefficients of digestibility by humans in one experiment 96 for protein, 97 for fat, and 88 for carbohydrates, and in another experiment, 98 for protein, 95 for fat, and 89 for carbohydrates but the second

experiment lasted only 2 days. With tofu cake (soybean residue) the coefficients were for protein, 78.7, for fat, 84.3, and for carbohydrates, 82.8. The coefficients of digestibility of yuba were 92.6 for protein, 95.7 for fat, and 86.8 for carbohydrates.

The results obtained in the different investigations indicate a very high degree of digestibility of the constituents, when it is properly prepared for food. The numerous food products prepared by Chinese and Japanese show that important constituents are more readily assimilated from them than from beans simply boiled.

Mature or Dry Soybeans.—Many schools of cookery and domestic science and the United States Department of Agriculture have shown that the dry or mature soybeans can be used satisfactorily after the manner of navy or other beans. Though the flavor, which differs with the variety, is not very prominent, soybeans are very palatable. The lighter colored varieties, yellow and green, are best for food, as the dark ones usually have a stronger, less pleasant taste; however, some of the light brown varieties have a very agreeable flavor.

Because of their high fat content and compact texture, most varieties of soybeans do not cook soft so readily as the navy or field beans. The method of cooking, however, may cause the beans to remain hard and tough. If cooked properly, soybeans do not require much longer soaking and cooking than the ordinary beans. One variety, the Easycook, has been found by the Department of Agriculture to cook fully as soft as the navy bean in less time after the preliminary soaking of 12 hours. Experiments with a large number of varieties have shown that the time required for cooking the beans tender varies to a considerable extent with the variety. The Haberlandt requires less time to cook tender than the Mammoth Yellow. When boiled, the beans can be used for baked beans, soups, croquettes, loaf, and many other dishes. In China the dried beans are soaked in water and roasted, this product being eaten after the manner of roasted peanuts.

Immature or Green Soybeans.—When soybeans are from three-fourths to full grown, the bean makes a most palatable and nutritious green vegetable (Fig. 58). The yellow, brown, and green seeded sorts are excellent for this purpose, being shelled and cooked like lima or other green or immature beans. The pods are rather tough and not desirable to eat. The beans are

rather difficult to remove but after cooking in the pods for about 5 minutes shell out very easily. These beans may also be canned the same as green peas or lima beans and make an excellent green vegetable. One large canning company has successfully canned green soybeans on a commercial scale. As they are much cheaper than lima beans and equal in quality, this promises to become an important industry.

The composition of the soybean when about full grown is as follows: Moisture, 70.24; protein, 10.53; fat, 5.68; starch, 2.00; sugar, 2.59; fibre, 1.98; ash, 1.92.

Fig. 58.—Seeds and pods of the Hahto variety of soybeans, the seeds being especially valuable as a green vegetable.

In preparing for the table, cook the beans until tender, changing the water once. Season with salt, pepper, and butter or combine with a white sauce made from one cup of milk, two tablespoons of flour, and one tablespoon of butter.

Soybean Flour.—Soybean flour, though as yet not a common commodity, has been used for many years in America and Europe in invalid dietetics. This flour which is made by grinding either the whole beans or the press cake remaining after the oil has been removed from the bean, is becoming an important article of food in America and European countries as it is of high food value and can be used as one of the ingredients of many palatable and nutritious dishes.

Utilization and Products.—Extensive investigations have been conducted by the United States Department of Agriculture and Domestic Science Schools relative to the utilization of soybean flour. It has been found that this flour can be successfully used as a constituent for bread, muffins, biscuits, crackers, macaroni, and in pastry. In these various food products about one-fourth soy flour and three-fourths wheat flour have been found to be the proper proportion. In some of the pastry products, however, as much as one-half soy flour can be used. It will be found that in several dishes, as soybean mush, soy flour can be used entirely.

In the United States soybean flour is on the market, being put up like ordinary cereal flours; also in special packages for invalids. In England, manufacturers have placed on the market a so-called "soya flour" which is 25 per cent. soybean flour and 75 per cent. wheat flour. This soya flour is being used by bakers in making a soy bread which is very palatable and is extensively used by the English bakers. A similar flour is said to have been manufactured in Holland for 25 years. Soya biscuits and crackers are also manufactured from this flour and constitute articles of export from England.

German millers have been experimenting to some extent with soy flour in making brown bread by mixing with rye flour. As to the extent to which this bread is used, no data are available, but it is known that soybean flour, on account of the large proportion of protein and phosphates it contains, as well as the palatable products made from it, found favor as a foodstuff. Soybean flour enters largely as a constituent in many of the so-called diabetic breads, biscuits, and crackers manufactured as food specialties. It also is utilized in the manufacture of breakfast foods and can be used in the preparation of vegetable milk and bean curd.

Composition and Value for Invalids.—The soybean contains at the most but a slight trace of starch, and extensive experiments in American and Europe indicate the value of the bean and its products as the basis of foods for persons requiring a low starch diet. When a special food of low starch content is desired, as for diabetic persons, a larger proportion of soy flour is used and some form of gluten is substituted for the wheat flour. The addition of soy flour changes the proportion of protein and carbohydrates in the mixtures as will be noted from the composition of flours shown in Table XCIII.

Table XCIII.—Composition of Soybean Flour in Comparison with Wheat Flour, Corn Meal, Rye Flour, Graham Flour, and Whole Wheat Flour

Flour or meal	Constituents, per cent.					
	Water, per cent.	Ash, per cent.	Fat, per cent.	Fiber, per cent.	Protein, per cent.	Carbohydrates, per cent.
Soybean[1]	6.14	5.24	20.71	1.72	39.56	26.63
Soybean[2]	6.10	6.20	4.50	2.05	47.30	33.85
Wheat	12.00	0.45	1.00	0.20	11.00	77.35
Corn meal	10.00	0.90	2.70	0.80	8.50	77.10
Rye	9.00	1.10	1.50	0.65	12.00	75.85
Graham	9.60	1.80	2.20	1.90	12.60	71.90
Whole wheat	10.90	1.05	2.00	1.00	12.00	73.05

Friedenwald and Ruräh (1910) concluded after a series of investigations that the soybean is a valuable addition to the dietary of diabetics on account of its palatability and the numerous ways in which it can be prepared. It was also found that the soybean in some ways causes a reduction in percentage and total quantity of sugar passed in diabetic subjects on the usual dietary restrictions.

Value for Infants.—In view of the difficulty to supply sufficient protein that can be digested and assimilated in the feeding of infants and some young children, Ruräh (1910) carried on investigations with the soybean as an article of food. In summer diarrhea and certain forms of intestinal disturbances, a weak gruel (one to two level tablespoonfuls to the quart), made from soybeans, or, preferably from the gruel flour of the bean was found of great value. As a rule it was well borne and digested, and rarely causes either vomiting or an increase in diarrhea.

After more extended investigations Ruräh (1915) states that mixtures of condensed milk and soybean gruels will be found one of the most valuable additions to the dietary of the infant. The class of cases and circumstances in which this mixture is to be advised is outlined as follows: When fresh milk cannot be obtained, or when the milk supply is very objectionable; in summer, when there is some question concerning the milk supply, and then in

[1] Flour made from the whole bean.

[2] Flour made from soybean cake. Analyses made by Bureau of Chemistry, U. S. Department of Agriculture.

instances where the infant is found to be incapable of digesting cow's milk. It may also be of service in cases of chronic vomiting, and particularly as a food after summer diarrhea. After 6 years of experience this investigator states that the soybean can be used without any danger. It permits a perfectly normal development as far as bones are concerned, and in successful feeding the infants present the appearance of breastfed babies.

Digestibility of Soybean Flour.—Bowers (1919) made rather extensive investigations on the nutritive value and digestibility of soybean flour. It was found that the protein of the flour when thoroughly cooked is about 91 per cent. digestible by man (making metabolic corrections), thus comparing favorably to the proteins of patent wheat flour. The carbohydrates, although consisting largely of dextrin, pentosan and galactan, are about 94 per cent. digestible. It was proven in more extended study of the digestibility of the different carbohydrates taken separately that the sucrose, amounting to about 3 per cent., is practically 100 per cent. digestible; the raffinose amounting to about 1 per cent., is thoroughly digestible; the dextrins are essentially 100 per cent. digestible; the slight amount of starch, amounting to less than 1 per cent., is thoroughly digestible; the hemicelluloses, amounting to about 6 per cent., are about 93 per cent. digestible; and, the cellulose is about 77 per cent. digestible. The calcium oxide content of soybean flour was found to be 0.27 per cent., and phosphorous pentoxide 1.52 per cent. No salicylic acid was found in the flour, and no hydrogen cyanide or cyanates were found. A very slight trace of tannin and also a slight trace of alkaloids were found in the flour.

Soybean Bran.—According to Bowers (1919) the bran of the soybean can be separated by milling more easily and more completely than can the bran of wheat. The bran makes up about 8 per cent. of the soybean and is composed chiefly of crude fiber and nitrogen free extract. The crude fiber amounts to about 37 per cent. and the nitrogen free extract to about 43 per cent.

Experiments with the bran show that the nitrogen free extract, including the hemicelluloses and the waxes, is about 84 per cent. digestible, which is much less than that of the whole bean. This is judged to be on account of the large amount of waxes in the nitrogen-free extract of the bran. A diet consisting of well cooked soybean bran appeared to have no ill effects. No noticeable

amount of gas indicating fermentation, as is the case with navy bean bran, was noticed with the soybean bran.

The calcium oxide content of the bran was found to be 0.8 per cent. and the phosphorous pentoxide content, 0.27 per cent. No salicylic acid was found in the bran, and no hydrogen cyanide or cyanates in the samples tested. There was no trace of tannin in the bran and only a slight trace of alkaloids.

Soybean Sprouts.—Sprouts grown from soybean seed are used extensively by the Chinese as a green vegetable in a great variety of dishes. Bean sprouts furnish a fresh vegetable dish during

Fig. 59.—The basket to the left of the photo contains sprouted, small, yellow soybeans, while the one on the right holds sprouted mung beans. (*Photographed by F. N. Meyer, Agricultural Explorer, U. S. Dept. of Agr.*)

the whole year, especially in the winter when green vegetables are scarce. The yellow- or green-seeded varieties are most generally used for growing sprouts.

In preparing the sprouts the beans are thoroughly washed and then poured into a large vessel (usually an earthen jar) which is about 3 ft. high and 1½ ft. in diameter. At the bottom of the vessel small holes are made for draining the excess water from the beans. A bamboo mat or cloth is placed at the bottom of the vessel to prevent the beans from running out of the holes. After the beans have been poured in, the vessel is covered with a straw cover to keep out the light. The beans must be moistened at least three times each day during the summer and twice a day during the winter. In the winter it is advisable to add warm water and keep the vessel in a warm place. The beans are usually kept in the vessel from 3 to 5 days in the summer and about 15 days in the winter. At the end of the time the sprouts

are fully grown ($1\frac{1}{2}$ to 2 in. long) and ready to be used or taken to the market for sale (Fig. 59).

Bean sprouts are considered a great relish and are eaten as a common vegetable throughout the whole year. The sprouts are sometimes boiled with salt, bean oil, or rape seed oil. They are also boiled and eaten with rice and millet. Salads of various sorts may also be prepared with the sprouts as the chief ingredient. The sprouts, in fact, may be utilized in almost any way that green vegetables are used and require only a very short cooking.

The Mung bean (*Phaseolus aureus*) is perhaps used more generally then the soybean for sprouts. The following table gives the composition of the sprouts obtained from the soy and mung beans according to Li Yu Ying and Grandvoinnet (1911–1912).

TABLE XCIV.—COMPOSITION OF THE SPROUTS FROM THE SOYBEAN AND MUNG BEAN

	Soybean	Mung bean
Water	66.98	91.21
Nitrogenous materials	14.73	3.41
Fat	5.95	0.28
Carbohydrates	4.04	2.12
Mineral salts	3.41	0.48

Soybean Coffee.—When properly roasted and prepared, the dried beans of any variety of soybeans make an excellent coffee substitute. As such the soybean has been used to a slight extent for many years in Europe, especially Switzerland, and in the United States. It is recorded that during the period of the Civil War the soybean was used rather extensively in the southern states as a coffee substitute. For a considerable while seedsmen sold the Ito San variety under the names Coffee Berry and Coffee Bean. In Japan and southern Russia soybean coffee is prepared and put up in small packages for the market. This product is ground very fine and has much the appearance of coffee essence.

Prepared as coffee, the soybean gives a liquid of the same color and odor as coffee and somewhat the flavor of a cereal beverage. Those fond of cereal drinks pronounce the soybean beverage equal to the best of the preparations on the market. According to

Li Yu Ying and Grandvoinnet (1911–1912) the soybean dried and roasted, such as is used in Switzerland, has the following composition: Water, 5.27; cellulose, 4.97; carbohydrates, 34.76; fat, 18.01; total materials soluble in water, 49.07.

Soybean or Vegetable Milk.—Soybean or vegetable milk is said to have been originated by the Chinese philosopher, Whai Nain Tze, long before the Christian Era and is known to the Chinese under the name of Fu Chiang or bean curd sauce. This is not only used in the fresh state by the Chinese but is

Fig. 60.—Machinery with which the soybeans are ground and the milk strained. Note the two grinding stones and the cloth strainers suspended from the ceiling over the tub. The cabinet with rack for bottles is noted in the background.

also condensed by the Japanese the same as cow's milk. It also forms the basis of the various kinds of bean curd or vegetable cheese which are so extensively used throughout the Orient. Attempts have been made at various times to place this bean milk on the market in European countries and America but without much success. In some parts of the United States, vegetable milk is used in special cases and attempts are being made to manufacture this milk in the form of a powder on a commercial scale.

Preparation of Soybean Milk.—The straw-yellow or yellowish-green seeded varieties of soybeans are always used in the manu-

facture of vegetable milk. The beans are first thoroughly washed and then soaked in water for several hours. This soaking causes the beans to swell up and is said to facilitate the extraction of the bean proteids. After the beans are soaked they are ground through a native mill (Fig. 60) which consists of two pieces of flat circular stone, one on top of the other. The top stone is turned around by hand against the lower one. The beans are fed through a hole near the edge of the upper stone and the fluid flows out between the two stones and is allowed to run into a tub. In the modern factories motor stone mills are used for crushing the beans (Fig. 61). The crushed mass is strained through a cheese cloth, diluted with water (usually three times the amount of water as there is of bean material) and boiled. After boiling, it is again strained and the white milk run off into containers.

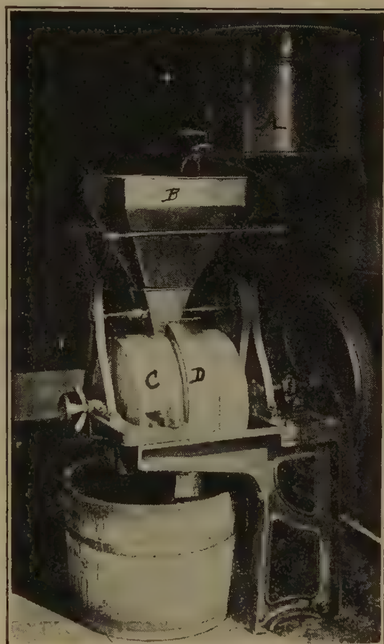

FIG. 61.—Motor stone mill for grinding soybeans in preparing tofū (bean curd). (*a*) Brass water tank. (*b*) Funnel reservoir. (*c*) Stones. (*d*) Brass guard.

Soybean cake or meal from which the oil has been extracted can be successfully used in the preparation of vegetable milk. The whole bean meal or flour can be used in the same manner and gives fully as good results as the Chinese method of soaking the beans. This method of preparing the milk from whole bean flour offers rather a convenient manner of preparing the milk and at the same time greatly reduces the amount of time. The beans may be ground through a coffee mill or small hand-mill. Either with the extracted meal or whole bean meal, one part meal and seven parts water are required. The meal is added to the boiling water and the mixture boiled for 10 minutes stirring constantly. Experiments with the different methods of preparing the milk have shown that as much bean curd can

be obtained by use of the meal as with soaking the beans and crushing, the latter being the method used in the Orient. After the meal and water are boiled, the mixture is strained through a cheese cloth. If a more concentrated milk is desired, the proportion of water may be reduced.

Composition of Soybean Milk.—The composition of vegetable milk will vary with the variety of beans used and with the method of manufacture. This milk is quite comparable to animal milk as shown in the following table.

Table XCV.—Composition of Soybean Milk Compared with Cow's Milk. Compiled from Various Sources

Kind of milk	Water, per cent.	Protein, per cent.	Fat, per cent.	Carbohydrates, per cent.	Other substances, per cent.	Ash, per cent.
Soybean...........	92.00	3.70	2.00	1.80	....	0.50
Soybean...........	80.00	4.95	2.97	1.34	....	0.44
Soybean...........	89.25	3.15	3.10	3.02	1.02	0.45
Soybean...........	92.50	3.02	2.13	0.03	1.88	0.41
Cow..............	86.06	3.05	4.00	5.00	1.19	0.70

According to Prinsen (1896) the fresh filtered milk has an alkaline reaction but Bloch (1906) found an acid reaction. Li Yu Ying and Grandvoinnet (1911–12) have always found in their investigations that the milk has an acid reaction and the grain itself reddens litmus paper. The properties of soybean milk may be said to be similar to those of animal milk. Acids, rennet, pepsin and certain salts will precipitate the proteid materials as with animal milk (see bean curd). Li Yu Ying and Grandvoinnet (1911–12) found that the lactic ferments act in the same way both with vegetable and animal milk. The ferments of certain European cheeses act similarly upon vegetable milk. Rennet curdles vegetable milk but the temperature is raised a little more than with cow's milk. The ferments which have been extracted from soyu exercise the same coagulative action upon animal and vegetable milk.

As vegetable milk is artificial, it is quite evident that the composition can be varied somewhat. However, there is a maximum which can not be exceeded if a complete dissolution is obtained. This is said to be reached with about 80 per cent. water.

Residue from Manufacture of Vegetable Milk.—After separating the milk from the solid material, the residue is still very rich in nutritive substances. According to Bloch (1907) and Li Yu Ying (1911–12) this material contains no trace of starch. Bloch (1907) gives the following composition of this vegetable milk residue: Water, 88.75; nitrogen, 0.248; ash, 0.36; fat, 0.04; and other substances, 10.85 per cent.

Utilization of Soybean Milk.—Vegetable milk has rather a strong characteristic taste and odor, somewhat suggesting malt. These may be masked by the addition of a small quantity of coumarin or vanillin. Vegetable milk may be used the same

Fig. 62.—Photograph of delivery coolies showing the way soybean milk is delivered by the factory in Changsha, China. The bottles in use there are purchased secondhand on the streets in Changsha. They are cleaned and when filled with milk are sealed with paper.

way as cow's milk. In China this milk is drunk by the Chinese in the early morning with some sugar added. It is also eaten as a thin broth with salted pickles. Vegetable milk is extensively used throughout China for infant feeding. In many of the cities and towns of China, factories are engaged solely in the manufacture of vegetable milk. This milk which is bottled is delivered (Fig. 62) each morning to regular customers.

Investigations in America and Europe with vegetable milk indicate that it may be successfully used in place of cow's milk in numerous preparations. The milk has been used with good results in bread, cakes, in creaming vegetables, in custards, in chocolate or cocoa, and in milk chocolate. In special therapeutic cases, vegetable milk has been used successfully in place

of animal milk and is said to rank closely to mother's milk in infant feeding. If allowed to remain in a warm place, the milk becomes sour, like animal milk, and in that form may be employed just as is sour milk or buttermilk. Various ferments may be also used to bring about this condition.

The milk made from the soybean also serves as a check on the very prevalent summer diarrhea common to children. Sinclair (1916) experimented on babies, who had various ailments, and found that soybean milk brought improvement in the great majority of cases, curing diarrhea and intestinal disturbances. It was also found that the milk was easily digested and easily excreted.

Condensed Vegetable Milk.—In Japan a concentrated or condensed milk is prepared from vegetable milk after the addition of sugar by evaporation. This condensed vegetable milk, though not so pale in color, resembles in nutritive value and keeping qualities condensed cow's milk. Katayama (1908) conducted rather extensive investigations with this product. It was found that on direct evaporation after addition of sugar the dissolved protein tended to separate into little flocculi. The addition of a small amount of dipotassium phosphate prevented this separation. In 4 liters of vegetable milk, Katayama (1908) dissolved 4 g. of dipotassium phosphate and 600 g. of sugar. This solution was then concentrated in a vacuum to a very thick liquid like condensed milk. The investigator is of the opinion that this condensed vegetable milk can replace the more expensive cow's milk for culinary purposes, for sweetening coffee and tea, and in the preparation of chocolate.

Investigations were conducted by Katayama to find if the adulteration of condensed cow's milk with vegetable milk could be easily detected by chemical means. It was found that if upon the addition of sodium carbonate, a yellow coloration resulted, the presence of vegetable milk was indicated. If a portion of the suspected milk is mixed with double of its volume of water and one-tenth distilled off after the addition of a few drops of diluted sulphuric acid, the characteristic odor of raw beans will develop. A further test consists in separating the casein of cow's milk with rennet and adding some calcium nitrate to the filtrate. A precipitate indicates the presence of the globulin of soy milk, the so-called glycinin.

Vegetable Milk Powder.—Vegetable milk can also be dried and

reduced to a powder. The method of preparing vegetable milk powder is the same as for the manufacture of powder from animal milk. Vegetable milk powder is very rich in protein and fat. The composition of this powder according to Li Yu Ying and Grandvoinnet (1911–12) is: Water, 7; protein, 46.04; fat, 27.60; carbohydrates, 12.36; and mineral salts, 6.0 per cent.

Fermented Vegetable Milk.—As fermented milks are being used to a greater extent in therapeutics, it is possible to replace successfully cow's milk with vegetable milk. The same ferments used with animal milk can be used with vegetable milk. If the carbohydrates are not sufficient in the vegetable milk, the addition of lactose will furnish the desired proportion. The advantages of using fermented vegetable milk are that it is economical and not so easily contaminated with injurious bacteria or ferments.

Vegetable Casein.—Vegetable casein can be prepared from soybean milk by precipitating the legumin from the milk, purifying by several washings and precipitations and finally by drying. The soybean casein obtained in this manner is a yellowish powder closely resembling animal casein prepared in the same manner. It is the general opinion that vegetable casein has a coefficient of digestibility much less than that of animal casein. According to the investigations of Labbé (1911), however, vegetable albumin is quite as readily assimilated as animal albumin. While vegetable casein has some differences from animal casein, about the same differences exist between the caseins of different animals.

According to Beltzer (1911), the manufacture of vegetable casein from the soybean has become an established industry in Cochin China. The extraction of the casein for industrial purposes is obtained from the meal, after the extraction of the oil from the bean. The cake or meal coming from the oil press is ground under millstones with cold water, and the homogeneous milky material thus obtained, after kneading in the vats, is passed through a filter press. The residue is subjected to the same process and a second lot of milk obtained. The milky fluid is poured into cylindrical wooden vats and heated to the boiling point by tinned copper worms. To each 1,000 liters of liquid 1 kilogram of calcium sulphate (plaster of paris) is added. This causes a precipitation of the vegetable casein which is collected on cloth filters. It is now dissolved in diluted soda lye, weak enough for the reaction to be neutral or slightly alkaline.

Then after filtering it is precipitated with acetic acid, left to evaporate in the open air, and the precipitate dried at a low temperature. One hundred grams of soybean seed yields about 25 grams of casein.

The casein obtained from the soybean can be employed in the same ways as animal milk. This vegetable casein is utilized for food and for industrial purposes. The various uses of soybean casein are: Medium for paints, dressing for textiles, size for paper, Galalith, waterproofing for textiles, etc. As a food it is used as "Soy-casein," a flour like Nestle's, with which sauces, bread, jam, milk, fermented milk, cheese, and concentrated biscuits may be made.

Tofū or Soybean Curd.—When a mineral salt or acid is added to soybean milk, coagulation is produced which is similar to that produced by the same means in animal milk. If the precipitated mass is allowed to drain and is subsequently washed, a sort of white cheese or curd is produced. This cheese is called "Teou fu" by the Chinese, "Tofu" by the Japanese, and "Dan Phu" by the Annamites. It is said to have been originated by the Chinese philosopher, Whai Nain Tze, before the Christian Era, and was undoubtedly introduced into Japan from China by the Buddhists. For the Buddhist priests, as well as the strict adherents to Buddhism who eat no animal food, it forms a very popular and almost indispensable article of diet.

Method of Manufacture.—The method of manufacture of bean curd varies to some extent in different parts of the Orient. The first stages of manufacture are the same as for the production of soybean milk. A small quantity of magnesium chloride (about a 1 per cent. solution) which has been previously dissolved in hot water, is mixed thoroughly in the hot milk. Through the action of the magnesium chloride, the proteids are coagulated. The water which accumulates on the top is partly drawn off and thrown away. The solid substance which remains is dipped out when still warm into square wooden trays about 3 in. deep, in which cloth has been previously spread. The ends of the cloth are folded over and a bamboo lid or board placed upon it. It is then subjected to pressure by piling several trays together with stones on the uppermost one to drive out the moisture and shape the curd to the size of the tray. After the water has been pressed out sufficiently, the cake of bean curd is just solid enough to stand handling and is ready to cut into small squares

(Fig. 63) and sold for consumption. This bean curd is a whitish-gray mass of the consistency of cream cheese.

Bean curd may also be manufactured from whole soybean meal and the cake remaining after the extraction of the oil. The meal is added to 5 times the amount of boiling water and boiled for 10 minutes. The milk is then filtered off and brought to the boiling point. A 1 per cent. solution of magnesium chloride is added, using it in the ratio of about 1 of solution to 4 of milk. Experiments by the junior author with various methods of manufacture indicate as good results are obtained with that just described as with methods where the beans are soaked and crushed. When powdered gypsum is used, about 11 oz. are required for each 40 lb. of beans.

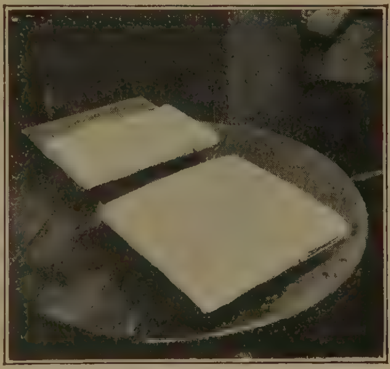

FIG. 63.—Large blocks of freshly made bean curd "Tofu" ready to be cut up into squares and sold for breakfast. (*Photographed by F. N. Meyer, Agricultural Explorer, U. S. Dept. Agr.*)

Coagulating Agents.—The coagulating agents most generally employed throughout the Orient are the concentrated mother liquid obtained in the manufacture of salt from sea water, burned powdered gypsum, and magnesium chloride. Bloch (1906) has tested various mineral salts in their effect of coagulating the proteids of soybean milk. The results obtained show that the chlorides and nitrates of calcium, barium, strontium, magnesium, and magnesium sulfate coagulate soybean milk. Li Yu Ying and Grandvoinnet (1911–12) obtained coagulation with rennet. The junior author has obtained successful results with rennet and 1 per cent. solutions of acetic, tartaric, and lactic acids. Sour milk has also given satisfactory results as well as the water drawn from the bean curd after coagulation. By the use of pure salts or rennet the bitter taste which is generally found in the curd made by Oriental methods is avoided.

Manufacturing Yields.—Where the manufacture is carried on commercially it is said that about 250 lb. of bean curd are obtained from 70 lb. of beans. According to Champion (1885) 120 grams of beans produced 184 grams of curd and Paillieux (1880) found 1 kilo of beans to yield 1 kilo 500 grams of curd.

The amount of curd obtained according to Oriental methods depends on the amount of water used in making (including the amount of water used in grinding), the quality of the beans and the completeness of grinding.

The junior author has conducted a large number of tests to determine the yield of curd from different varieties. The following table gives the results obtained with varieties in which the percentage of protein ranged from 32 to 45. The method of manufacture of curd from each variety was conducted under identical conditions. Whole bean flour or meal and a 1 per cent. solution of agnesium chloride (in the proportion of 1 of solution to 4 of soybean milk) being used. The moisture was pressed out more thoroughly in each case than is ordinarily done in the commercial manufacture of the curd. This accounts for the lower yield of curd obtained from the amount of bean material used as shown in Table XCVI in comparison with the yields obtained in commercial manufacture.

Table XCVI.—Yields of Bean Curd Obtained from Different Varieties of Soybeans

Variety	Seed color	Protein, per cent.	Fat, per cent.	Beans, grams	Curd, grams	Cake, grams	Color of curd
37062	Straw yellow......	40.00	20.53	50	34.3	30.5	Cream
38218	Straw yellow......	39.80	16.46	50	33.2	30.2	White
36576	Straw yellow......	38.25	19.56	50	31.7	31.6	Cream
36833	Brown............	40.90	15.99	50	30.5	30.2	Gray
37236	Olive yellow.......	.....	.....	50	29.0	32.6	Cream
40371	Straw yellow......	38.44	16.72	50	28.2	31.6	Cream
39969	Brown............	38.94	15.03	50	27.3	31.4	Gray
37318	Yellow & Black....	38.56	19.21	50	26.1	31.9	Gray
37282	Green............	41.00	16.40	50	25.4	31.9	Greenish
40117	Olive yellow.......	42.05	13.55	50	24.0	31.0	White
37251	Straw yellow......	41.30	15.62	50	23.1	33.8	White
37342	Brown............	.....	.....	50	22.0	32.8	Gray
40115	Straw yellow......	36.88	15.45	50	21.0	32.9	White
37080	Olive yellow.......	.....	.....	50	20.0	32.9	White
37335	Straw yellow......	38.06	17.43	50	19.1	33.9	Cream
37247	Straw yellow......	42.01	14.30	50	17.9	33.8	
37050	Black............	.....	.....	50	17.1	36.2	Slate
35627	Green............	44.7	14.26	50	16.6	32.6	Greenish
38462	Black............	31.94	16.35	50	14.1	34.8	Slate

Composition of Soybean Curd.—Tofu or soybean curd consists principally of the protein matter of the soybean. Inoyŭe (1897) in a study of the preparation and chemical composition of tofu concludes that in the soybean there are contained compounds of casein with potassium or sodium which are not coagulated by boiling but which yield with the calcium and magnesium salts of the brine that precipitate of insoluble calcium and magnesium compounds of the casein that constitutes tofu. The separation of tofu is said to be due to precipitation and not to coagulation. Tofu is especially rich in protein, in fat, and in mineral substances which seems to justify the Chinese proverb "Tofu is the meat without bone." About one-fourth of the total amount of the proteids in soybeans is contained in the bean curd. According to Inoyŭe (1897), tofu dried at 100° yielded 26.65 per cent. fat and 4.83 grams of this fat yielded 0.280 grams of magnesium pyrophosphate, which gives 2.035 grams lecithin, amounting to 11.2 per cent. of dried tofu, leaving for the genuine fat 15.4 per cent.; more of the latter, therefore, is left in the refuse than of the former. A portion of the lecithin is said probably to be present in the soybean as lecith-albumin. The following table gives the compositions of tofu and tofu products, according to different investigators.

TABLE XCVII.—COMPOSITIONS OF TOFU AND TOFU PRODUCTS. COMPILED FROM VARIOUS SOURCES

Product	Moisture, per cent.	Protein, per cent.	Fat, per cent.	Carbohydrates, per cent.	Ash, per cent.
Fresh tofu	88.11	6.29	3.38	1.64	0.58
Fresh tofu	89.29	4.87	....	4.35	0.48
Fresh tofu	90.37	6.13	2.36	....	0.76
Fresh tofu	89.00	5.00	3.40	....	0.50
Fresh tofu	83.85	8.00	4.33	....	0.37
Frozen tofu	18.72	48.65	28.65	2.33	1.65
Fried tofu	57.40	21.96	18.72	0.57	1.35

Digestibility of Soybean Curd.—According to the results of digestion experiments by Oshima (1905), the digestibility of the nutrients in bean curd was found to be high. As much as 95 per cent. of the protein is digested and about the same proportion of fat. The carbohydrates were found to be somewhat less digestible when the tofu was eaten alone, but when eaten with rice

about 99 per cent. of the total carbohydrates of the diet was digested. It is quite evident that bean curd is not only a very rich substance but is composed of constituents easily assimilated.

Utilization of Bean Curd and Manufactured Products.—Bean curd when fresh is rather a tasteless product but it can be and is used as the basis of a great variety of preparations. According to the greater amounts of coagulating material added and pressure applied, curds of different degrees of consistency can be prepared (Fig. 64). Bean curd can be prepared for preservation and transportation. It is generally prepared each day and is

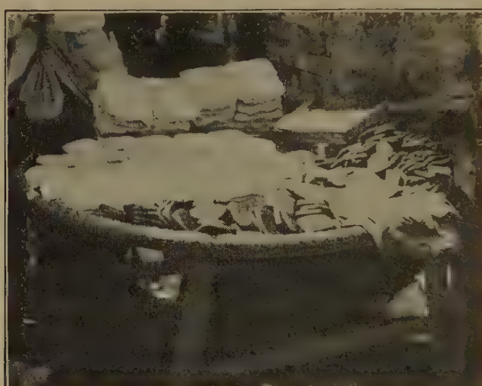

Fig. 64.—A large bamboo tray full of various kinds of bean curd. In the little wooden tubs on the ground the watery sorts of curd are kept immersed in somewhat saline water. (*Photographed by F. N. Meyer, Agricultural Explorer, U. S. Dept. of Agr.*)

eaten in the fresh condition simply with a little soy sauce though it is frequently cooked or fried. Following are the principal preparations of bean curd used in China:

Bean-curd Brains or Tofu Nao.—A substance of less consistency than the bean curd. It is prepared by adding only a very little magnesium chloride or gypsum and is not pressed. It is said to be eaten as a broth with sweet oil, sauce, and vinegar sprinkled over it. It is also eaten as a stiff broth with the addition of finely chopped meats and some spices.

Dry Bean Curd or Tofu Khan.—This bean curd is much like the ordinary bean curd, but instead of being white has a rich brown color which has been given by dipping the bean curd squares in burnt millet-sugar sauce. Fine salt also has been rubbed on them. This form of cheese can be kept for several days and is generally eaten in soups.

Thousand Folds (*Chien Chang Tofu*).—This product is prepared by placing very thin layers of the bean curd on cloths, on top of one another, and subjecting them to considerable pressure and allowing to dry for a short time. The layers of bean curd are then removed and rolled together like a jamroll. It is said to be eaten cut into strips, like noodles, in soups. When allowed to mold for several days it is fried in sesame oil and has a meat like flavor.

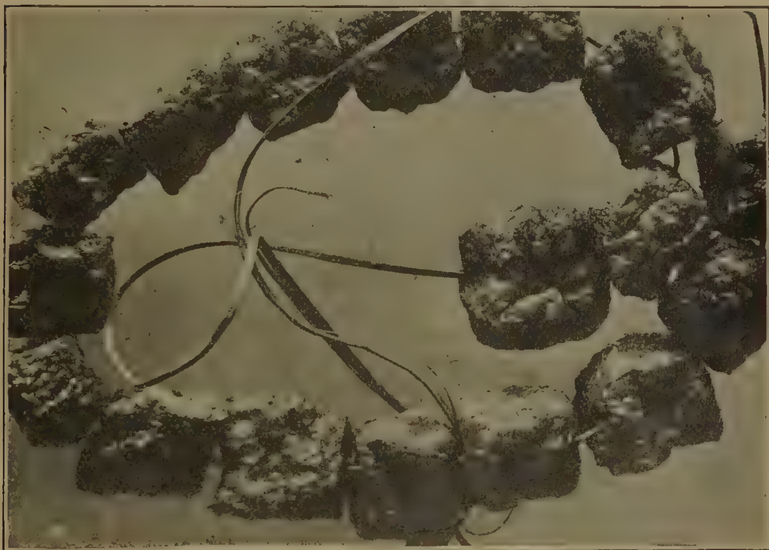

Fig. 65.—Squares of fresh bean curd fried in oil and put on a string of bamboo fiber. Called tza tofu (fried bean curd) and said to supply a "snack" in between meals for hard working Chinese laborers. (*Photographed by F. N. Meyer, Agricultural Explorer, U. S. Dept. of Agr.*)

Fried Bean Curd (*Tza Tofu*).—The fresh bean curd is cut into small squares and fried in deep fat. After a few minutes the bean curd pieces float on the surface and they are then taken out. This product is often fastened on bamboo fibers (Fig. 65) and may be kept for several days. They may also be eaten with syrup as fritters.

Fragrant Dry Bean Curd (*Hsiang Khan*).—This form is made like the ordinary bean curd but great pressure is applied to drive out as much water as possible. The squares (Fig. 66) are first soaked in a weak brine or bean sauce to which powdered spices and burnt millet-sugar have been added and then are thoroughly

dried out. The curd becomes very hard and can be kept indefinitely. It is said to be eaten sliced in soups and in various vegetable dishes.

Frozen Tofu (*Kori Tofu*).—Frozen bean curd is an excellent example of the application of the freezing process for the drying or concentration of a food. Fresh bean curd contains rather a high per cent. of water and is therefore a very unstable product. The fresh bean curd is cut into small pieces and exposed to severe cold weather. By freezing, the vegetable proteid shrinks and

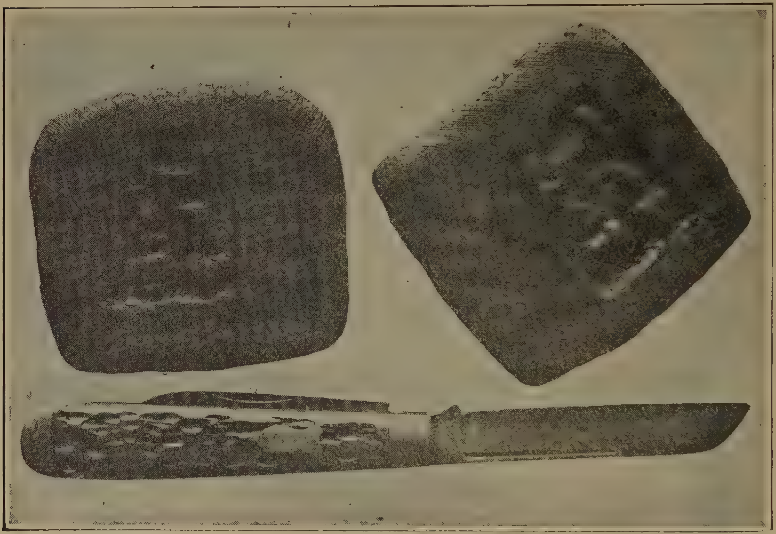

Fig. 66.—A semi-dry bean curd of the consistency of smoked sausage, called "Hsiang khan" (fragrant dry), which is eaten sliced in soups, and with vegetable dishes. (*Photographed by F. N. Meyer, Agricultural Explorer, U. S. Dept. of Agr.*)

forms a porous cake permeated with ice crystals. This frozen cake can be readily thawed out and dried. It forms a product much resembling gluten bread in appearance. If tofu is not frozen, it is difficult to dry and the resulting material is dense and horn-like. Frozen tofu can be preserved for several years and forms a suitable product for transportation. This form of tofu is soaked in water and then used in much the same manner as fresh tofu.

Chinese Preparation.—In addition to the above preparations, the Chinese preserve tofu in many other ways (Figs. 67, 68, 69). In a fresh state it can be kept for several days simply by putting it in water. Tofu is quite generally preserved in loaves (100 to

150 grams) which are cooked in a decoction of turmeric roots. It is also preserved with salt. Often the curd is cut into small pieces and preserved in rice brandy. When smoked, the curd also keeps very well and can be wrapped in tinfoil for the market. Smoked curd is prepared by cooking the curd in soy sauce diluted

FIG. 67.—A semi-dry fresh bean curd, called "Lao to fu" (old bean curd) said to be used by the poorer classes of Chinese for breakfast. (*Photographed by F. N. Meyer, Agricultural Explorer, U. S. Dept. of Agr.*)

with water (80 per cent. and 20 per cent. soy sauce) and after cooking the curd is smoked in the same manner as meat.

Various Dishes.—Numerous palatable and nutritious dishes can be prepared with tofu as a base by American and European methods of cooking. When cut into small pieces and cooked with an egg, it furnishes an excellent omelet. It also may be used as the principal ingredient in baked stuffed peppers. The fresh tofu makes an excellent salad or sandwich filling if the curd

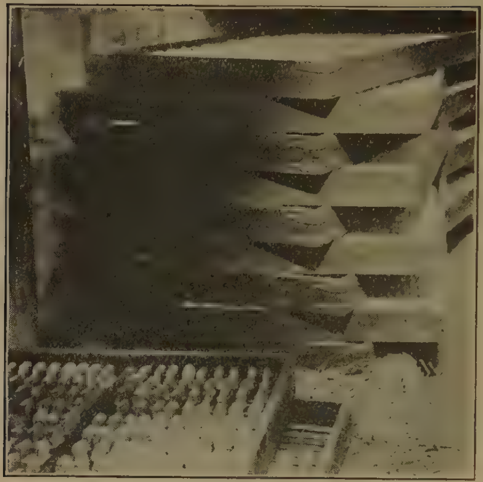

FIG. 68.—A dark room of even temperature where wooden frames, full of squares of bean curd are piled, one on the other, the lowest resting on a layer of somewhat damp rice straw. (*Photographed by F. N. Meyer, Agricultural Explorer, U. S. Dept. of Agr*).

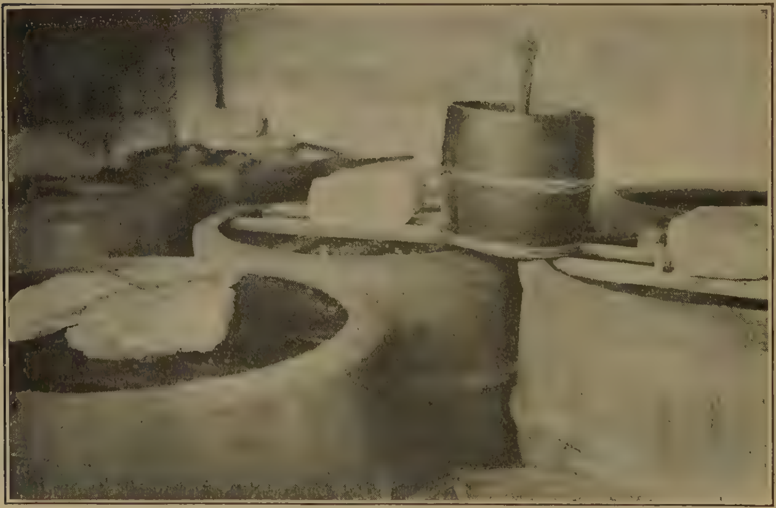

FIG. 69.—Large earthen jars, full of squares of bean-curd, which are covered over with spiced brine and soy-sauce. After several months' curing a new product has been formed, called "Foo-yu"—Bean cheese, which can be kept for many years and becomes better with age. (*Photographed by F. N. Meyer, Agricultural Explorer, U. S. Dept. of Agr.*)

is chopped finely and chopped olives, pepper, salt, and mayonnaise dressing are added. When cut into small pieces and cooked

FIG. 70.—Packing handful boiled soybeans into fresh rice straw wrappers in preparation of natto.

FIG. 71.—Fermenting room in which the wrapped soybeans are placed in the preparation of natto.

in tomato sauce or similar sauces, a very good meat substitute is obtained. Cooked with meat broth, the curd takes the flavor of the meat. It is readily seen that the fresh bean curd can be

utilized in many ways and when the people of the western world become better acquainted with its simple method of manufacture, it will no doubt, become more generally utilized.

Natto.—Natto, a sort of vegetable cheese prepared from soybeans, has long been used by the Buddhists and is now used extensively by the Japanese. Although it is made throughout Japan, the method of manufacture varies somewhat with the locality, the different kinds being associated with the place of manufacture such as Tokyo natto, Kyoto natto, etc.

In preparing natto, the soybeans are boiled in water for about five hours to render them exceedingly soft. The material while still hot, is wrapped in small portions (about a handful) in rice straw and the bundles, tied at both ends (Fig. 70) are placed in a cellar or room (Fig. 71) heated by hot water or charcoal. The room is then closed for about 24 hours, the temperature ranging from 35 to 40°C., this allowing the cooked beans to ferment in the warm moist atmosphere.

Another method is to put the cooked beans in a box with cut straw placed over and closed with a lid. The box is then placed in a stove for 24 hours at a temperature from 35 to 40°C. The fermented product is a thick viscid mass having a peculiar but not offensive odor. The amount of natto produced is about double the quantity of beans used.

Although the moderate heat of the cellar or rooms acts for only 24 hours, there is evidently a considerable bacterial fermentation. Yabe (1897) made rather an extensive study of the micro-organisms and chemical composition of natto. This investigator found one species of bacillus and three of micrococcus present and that the chemical decompositions of the proteids of the soybean must be due to one or more of these microbes. The principal chemical change concerned in the ripening of natto takes place in the protein. It is quite probable that a large proportion of the peptone and also leucine and tyrosin were products of the bacterial action. Although xanthin was formed, it was held doubtful whether or not the substances of the xanthin series were formed by the bacterial action. According to Yabe the determination of the different forms of nitrogen in the soybean and natto are shown in Table XCVIII.

In addition to being a highly nutritious food, it is quite probable that Natto is more easily digested than the soybean, as it is very soft and contains more peptone. The average composition of

TABLE XCVIII.—NITROGENOUS SUBSTANCES IN NATTO

Forms of nitrogen	Soybean	Natto from same soybeans
Moisture	15.160	59.120
Nitrogen of proteids (excluding peptone)	7.355	7.542
Nitrogen of amides	6.899	4.033
Nitrogen of peptone	0.128	1.892
	0.328	1.617

natto is as follows: Water, 61.84; albumen, 19.26; fat, 8.17; carbohydrates, 6.09; cellulose, 2.80; ash, 1.84.

Natto is used commonly as a side dish and also as a material for confections. It is usually eaten with drops of soy sauce.

Hamananatto.—Hamananatto, a kind of vegetable cheese prepared from soybeans, is manufactured principally in the central provinces of Japan. Although prepared much like miso and natto, it has a somewhat different flavor and texture from either of these. It has an agreeable salty taste and a peculiar odor somewhat resembling that of the fresh crust of brown bread. The soybeans composing it form no compact mass and are of a brown color with a thin layer of a salty taste and a somewhat sticky consistency.

In preparing Hamananatto the soybeans are thoroughly washed, boiled to softness, spread on straw mats and mixed with wheat flour (6 liters of flour to 10 liters of soybeans). Molds soon develop, after which the mixture is exposed to the direct sunlight for 3 days, probably to kill the fungi, and is then put in flat tubs. After about 12 days some salt and ginger are added. The entire mass is then kept in tubs under pressure for about 30 days.

Sawa in his investigations found that at least three different kinds of bacteria are present in this product. According to this investigator Hamananatto has the following composition:

TABLE XCIX.—COMPOSITION OF HAMANANATTO. AFTER SAWA

	PER CENT.
Albuminoid nitrogen	3.57
Fat	3.44
Fiber	6.87
Total carbohydrates, excluding cellulose	8.40
Total ash, including salt added	18.54
Moisture of fresh sample	44.73

Yuba.—When soybean milk is boiled, a film forms on the surface. This film, known as yuba, has been prepared since ancient times in China and Japan, and is a very popular foodstuff. It is very brittle and is sold in sticks, sheets, or small flakes. In cooking, yuba is used as a wrapper, cut into ribbons, or small pieces and either fried or used in soups.

In the preparation of yuba, soybean milk of the best quality is boiled for about one hour in a copper pan over a slow fire. A small quantity of auramine is added which tends to produce a thick film.

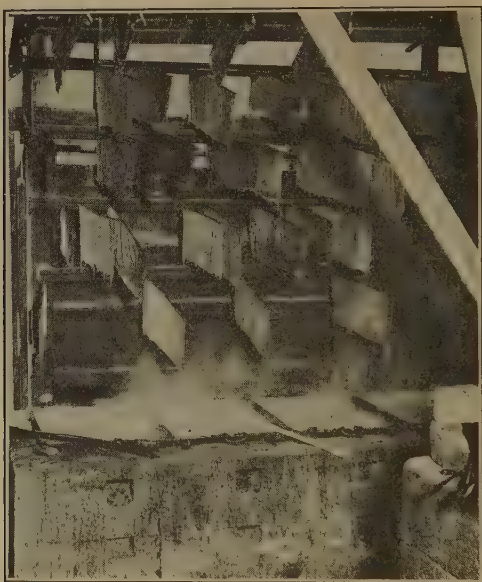

Fig. 72.—Showing the boiling of soybean milk in copper pans over a mild fire in the manufacture of yuba. The sheets of yuba are seen hanging in two-fold over sticks.

The film is removed from the milk by passing a stick underneath the surface, the film thus hanging on in two-fold (Fig. 72). It is dried slowly on a galvanized net over charcoal fire, resulting in a thin yellowish sheet.

The best quality of yuba is glossy and of a cream-yellow color. The first film is the best and the quality of the succeeding films gradually becomes inferior.

The milk obtained from 3 lb. of beans is said to produce about thirty sheets of yuba. The residue of the milk after

the films are removed is still rich in nutrients, and is used mostly for food. It also may be used as animal feed.

Yuba is valued chiefly on account of its high content of protein. It consists mainly of albuminoids and fat. The composition of yuba is shown in the following table.

TABLE C.—COMPOSITION OF YUBA

Authority	Water	Protein	Fat	Carbo-hydrates	Ash
Oshima	18.31	49.65	18.00	11.82	2.22
Nagao	22.85	51.60	15.62	7.31	2.82

Miso.—In extent of use miso is said to surpass all other preparations from the soybean in the Orient. It forms an

FIG. 73.—Preparing miso. On the right, the rice yeast tub. On the left, steaming the soaked soybeans in the tub.

indispensable part of the daily menu of the rural population and wage-earners but it is used somewhat less extensively among the people living in cities. It is the general custom of the people in rural districts to prepare miso for their own use. It has been estimated that the daily consumption of miso per person in rural districts in Japan is about 40 grams.

The preparation of miso depends primarily upon the action of a fermenting agent known as *kojii*, containing certain forms of fungi, of which *Aspergillus oryzae* is the principal one. The *kojii* also contains diastatic and inverting ferments which change the carbohydrates of the raw materials into maltose, glucose, etc., and a proteolytic ferment which acts upon the nitrogenous bodies, converting them into simpler and more soluble materials. In

Fig. 74.—Mill used for crushing the soybeans, yeast and salt mixture in the manufacture of miso.

preparing miso the beans are first steamed (Fig. 73) and upon this process depends largely the quality and especially the color of the final product. The beans are usually steamed for about 25 hours first with strong heat and later very gently. When the beans are properly steamed and cooked, they are rubbed into a thick, uniform paste, to which are added proper amounts of powdered kojii, salt, and water (Fig. 74). The whole mass is then well mixed and stored in a special vat (Fig. 75). The tempera-

ture of the mixture is kept at about 15° to 20°C., though as the fermentation advances it often rises to 25°C. The proportions in which the different ingredients of miso are employed are not always the same nor are the methods of applying them.

FIG. 75.—Packing the early cured miso.

There are many different kinds of miso which are distinguished by color, taste, and keeping properties, and are prepared by somewhat different processes, the differences consisting chiefly in the use of barley or rice kojii, the amount of common salt added, a

longer or shorter fermentation, and the temperature to which subjected.

White miso and red miso are the two most important kinds of this product. White miso, which contains but little salt, is fermented with rice kojii for 3 or 4 days only, and may be preserved for about 10 days. Red miso is red in color and contains a relatively large amount of salt. It is fermented usually with barley kojii for 1½ to 2 years, and may be kept for several years. The composition of these two kinds of miso, according to the investigations of Kellner (1889) is shown in the following table.

Table CI.—Composition of Red and White Miso

Kind of Miso	Water, per cent.	Dry matter, per cent.	Material soluble in cold water, per cent.	Protein, per cent.	Fat, per cent.	Fiber, per cent.	Starch, dextrin, etc., per cent.	Glucose, per cent.	Alcohol, per cent.	Common salt, per cent.	Total ash, per cent.
White	59.27	39.78	22.13	10.18	5.10	1.99	6.31	8.32	0.95	5.99	7.78
Red	50.16	48.66	32.98	12.48	6.46	2.31	2.72	10.40	1.18	10.84	12.48

The principal use of miso is in making soups and in cooking vegetables; for the latter purpose, miso and soy sauce are said to be to a certain extent replaceable. Miso is used also in preparing various other articles of food.

Shoyu or Soy Sauce.—Shoyu or soy sauce is a dark brown liquid with a pleasant aromatic odor and a peculiar salty taste, suggesting a good quality of meat extract, though perhaps more salty and a trifle more pungent. It is almost as indispensable to Asiatic people as rice. This sauce is very popular for use in cooking and as a relish or condiment to increase the flavor and palatability of the diet. It is estimated that about 2.5 oz. of soy sauce are consumed daily by each Japanese. When shaken, soy sauce foams up yellow and leaves behind on the side of the glass a clear shining line of a fatty appearance so that the Japanese designation "soy oil" (Sho-soy, yu-oil) is quite appropriate.

Manufacture.—The manufacture of soy sauce forms one of the important industries of Japan, the yearly production amounting to considerably over 2,000,000 bbl. It is also produced very extensively throughout the Chinese Empire and to some extent in India. The brewing of the sauce has also become a well-

established industry in Hawaii. As yet soy sauce is not manufactured in America[1] or in European countries, although large quantities are exported annually from China, Japan, and Hawaii, especially to the United States.

Various methods are employed in the manufacture of soy sauce, consequently many different grades of sauce are produced. The sauce is prepared from a mixture of cooked and ground soybeans, roasted and pulverized wheat (barley is sometimes sub-

FIG. 76.—Strong, small baskets placed in the center of large jars filled with fermented soybeans and brine. The soy sauce collects in the baskets and is dipped out ready for consumption. (*Photographed by F. N. Meyer, Agricultura Explorer, U. S. Dept. of Agr.*)

stituted in part for the wheat, as giving a sweeter taste), salt, water and a culture known as rice ferment (*Aspergillus oryzæ*). Four principal stages may be distinguished:

1. Preparation of the soybeans and wheat.
2. Preparation of the rice ferment (kojii).
3. The ripening process.
4. Pressing and boiling.

However, in some of the cheaper grades of sauce the pressing and boiling are omitted. As shown in Fig. 76 strong small baskets are placed in the center of large jars, full of fermented

[1] The attention of the authors has been called to the establishment of a factory in Columbia City, Indiana, for the manufacture of soy sauce.

soybeans and brine. The sauce accumulates in these baskets and is dipped out ready for consumption. This method of obtaining the sauce is undoubtedly local and apparently not as effective as the system by pressure.

FIG. 77.—The iron cauldron in which soybeans are boiled for the manufacture of soy sauce. (*After Groff.*)

In general, manufacturers use nearly equal parts of soybeans, wheat, and salt and about double the quantity of water. The density of the brine differs in the cheaper and in the better grades of the sauce. For the best grades of soy sauce, the ingredients are mixed according to Sawer (1910) as follows: Soybeans, 15 parts;

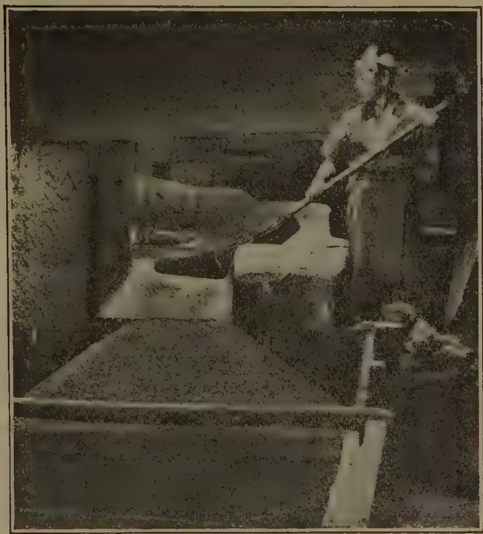

Fig. 78.—A pan used in parching wheat, the first stage of yeast making.

Fig. 79.—Fermenting room for yeast and soybeans in preparation of soy sauce.

FIG. 80.—Rows of pots filled with soybean and wheat mixture for soy sauce. (*Photographed by F. N. Meyer, Agricultural Explorer, U. S. Dept. of Agr.*)

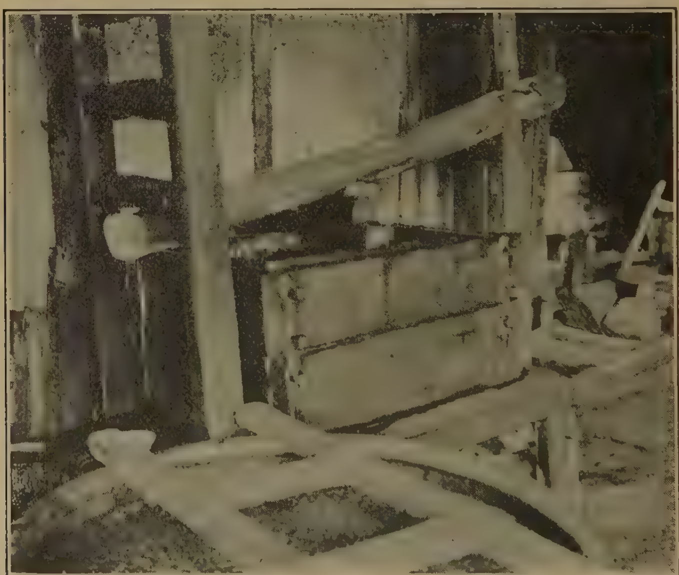

FIG. 81.—A box press in which sacks of fermented soybeans are placed for pressing out the liquid forming soy sauce. (*Photographed by F. N. Meyer, Agricultural Explorer, U. S. Dept. of Agr.*)

Fig. 82.—Kettle for boiling the soy sauce. After it is boiled, the sauce is ready to be placed in kegs at left side.

Fig. 83.—Soybean sauce ready for shipment. (*After Groff.*)

wheat, 15 parts; salt, 13.5 parts; and water 27.5 parts. Sahr (1913) in his investigations of the manufacture of soy sauce in Hawaii obtained the following data: 800 lb. of salt dissolved in 350 gal. of water to 1,000 lb. of beans produced 350 gal. of sauce; 500 lb. of salt dissolved in 150 gal. of boiling water to 400 lb. of soybeans gave 240 gal. of sauce and about 600 lb. of cass or soybean leavings.

For the manufacture of soy sauce the soybeans are first boiled in large iron vats or cauldrons (Fig. 77) from 4 to 6 hours and then left to cool for about 18 hours. This mass is mixed with an equal amount of wheat which has been browned in pans and pulverized (Fig. 78). The mixture is poured into molds which are in a long narrow chamber built of brick or stone, or sometimes in a sort of cellar with a temperature of about 36°C. (Fig. 79). Spores of the fungus *Aspergillus oryzæ* are added, the mass thoroughly mixed, and allowed to stand until slightly covered with the fungus. The salt is dissolved in boiling water in the proportions mentioned and added to the fermented mixture of beans and wheat. This mass is then emptied into large vats or jars (Fig. 80) and left to ferment from 6 months to a year, and sometimes as long as 5 years. During the process of ripening the mass is stirred thoroughly twice daily in the summer, but in winter only once every 2 or 4 days. The fermented mass, after ripening, is transferred into a large press (Fig. 81) and the liquid sauce is pressed out, boiled 2 or 3 hours (Fig. 82), and put into tubs of 4½- to 6-gal. capacity or small kegs or jugs (Fig. 83).

The solid moist mass left after the liquid is pressed out represents the soy cake or cass which is quite a valuable fertilizer and is sold to rice planters for this purpose. As it contains a comparatively large proportion of protein and fat, it is also utilized as a cattle feed, after soaking in water to extract the salt.

Chemistry.—Nishimura in his investigations of the chemistry of the manufacture of soy sauce found that the whole ripening process consisted principally in the action of the powerful enzymes of *Aspergillus oryzæ* upon the carbohydrates and proteids in the soybean and wheat, and further in the development of an agreeable flavor. The production of the small amount of lactic acid and acetic acid by bacteria does not seem essential. The great amount of salt added is intended principally to prevent bacterial growth and the resulting fermentations. The action of the enzymes is also much retarded by the salt. The same

author in experiments to shorten the time of manufacture, a most important desideratum, produced a sauce of very agreeable odor and taste like that of common soy sauce in 5 weeks. This shorter process was brought about by the thorough milling of the roasted wheat and boiled soybeans, the application of a temperature of 35 to 40°C., and the direct addition of alcohol. According to Oshima (1905) the chief chemical changes involved in the manufacture of soy sauce are those resulting from the action of proteolytic and diastatic ferments, and to some extent from the alcoholic ferments. By the proteolytic ferments, part of the proteid material of the soybeans is converted into forms more soluble than those originally present. The chief effect of diastatic fermentation is the production of glucose. The effect of alcoholic fermentation is more noticeable in the earlier states of manufacture. The decrease in the quantity of alcohol as fermentation advances is said to be probably due to further decomposition of alcohol into acid and other products which produce agreeable flavors.

Value and Composition.—Soy sauce is not only valuable as food because of the proteids and carbohydrates it contains but also on account of the peculiar and appetizing flavor which imparts a relish to other foods with which it is used. The general composition of soy sauce is shown in the following table:

Table CII.—Composition of Shoyu or Soy Sauce. Compiled from Various Sources

Specific gravity	Water	Protein	Carbohydrates		Free Acid (as lactic)	Ash	Salt	Phosphoric Acid
			Glucose	Dextrin				
1.185	62.39	9.28	2.70	0.69	1.18	18.48	16.03	0.53
1.190	62.82	9.53	3.33	0.69	1.33	18.70	15.67	0.51
1.208	60.58	9.15	5.85	1.43	0.92	20.14	17.47	0.46
1.230	60.08	6.75	3.33	1.10	0.80	.....	23.01–	0.39

Soybean Confections.—In Oriental countries the dried seeds of many legumes are used in the preparation of numerous sweetmeats and confections. The dried beans are often boiled in syrup and served as candied beans, the soybean being used to a

less extent in this manner than some other beans. The soybean is most often ground into a powder and used in pastry products or the beans are roasted and then ground into a fine powder or flour, which with sugar added is used as a filling for different sweetmeats such as little cakes or cookies.

The manufacture of a milk chocolate of which the roasted soybean ground into a fine powder is being placed on a commercial basis in Canada and the United States. Li Yu Ying and Grandvoinnet (1911–1912) prepared a chocolate from the soybean by adding sugar and cocoa butter. This product is said to have nearly the same composition, appearance and taste as chocolate.

In China and Japan the dried beans are soaked in water and roasted, the product being eaten after the manner of roasted peanuts. This method of preparing the beans is improved by soaking the beans for about 12 hours in a 10-per cent. salt solution, boiling slowly for about one-half hour and then roasting to a light brown color. The yellow-seeded and green-seeded varieties are preferable as they make a product of better appearance and flavor.

The roasted beans may be ground into a fine paste and with the addition of a refined oil, as peanut oil, mixed thoroughly through the paste, a sort of butter, resembling peanut butter, may be prepared. This product, if the beans are roasted simply to a light brown color, has much the same appearance as peanut butter and a very agreeable flavor.

The composition of the same variety of soybean before soaking in the salt solution, after soaking, and after roasting is given in the following table:

Table CIII.—Composition of Soybeans of the Same Variety Dried, Soaked, and Roasted[1]

	Dried beans, per cent.	Soaked beans, per cent.	Roasted beans, per cent.
Water	7.80	53.90	3.57
Ash	4.74	2.93	6.80
Protein	37.62	18.31	39.62
Fat	16.66	8.62	17.32
Total sugar	10.67	5.60	10.54
Fiber	4.28	1.98	5.25
Weight per 1,000 grams	273.4	570.4	229.5

[1] Analyses made by Bureau of Chemistry, U. S. Dept. Agric.

CHAPTER XIV

TABLE DISHES OF SOYBEANS AND SOYBEAN PRODUCTS

From the soybean and its products a very wide variety of table dishes may be prepared. Some of these are quite like other foods used by Americans and Europeans, but many are peculiarly Oriental. All are highly nutritious, and many of them of peculiar and delightful flavor and palatability.

Mature or Dried Beans.—Experiments by the Office of Home Economics, U. S. Department of Agriculture and by the Home Economics department of many colleges have shown the mature or dry soybeans can be used in many palatable ways. The ordinary varieties of soybeans as the Mammoth, Midwest, Ito San, etc., require a longer period of soaking and cooking than navy beans. The Easycook and Hahto varieties need no more preparation than the ordinary bean as they cook up very readily. Time may be saved by using a pressure cooker for they soften very readily when thus treated. In general it is well to soak the beans and then cook them until soft. The time required will vary with the dryness of the bean and also with the variety. After soaking for 20 to 24 hours the beans should be cooked until they are well softened which may require as much as 2 hours, or more. Better results are obtained if the beans are allowed to simmer rather than boil rapidly. A fireless cooker with hot plates can be used to advantage, a second heating being given if the first is not enough to soften the beans.

As the beans contain so much fat, it is obvious that they do not need fat meat added to them in cooking to supply this constituent, though some prefer to use a very small quantity to give flavor. Onions, tomatoes, and other seasoning vegetables are palatable additions to soybean dishes.

There are many appetizing ways in which soybeans may be prepared besides "plain boiled" and baked. The following recipes for cooking soybeans offer nourishing and palatable dishes:

Boiled Soybeans.—Soak 2 cups dried soybeans for about 12 hours. Drain, then add water, one-quarter teaspoonful soda, and cook just below the boiling point for 2 hours or until the beans are slightly softened. If allowed to heat too rapidly, the beans tend to become hard. The double boiler is good for cooking as slow cooking is desirable. The fireless cooker may also be used advantageously; boil the soaked beans for one-half hour and finish cooking in the fireless cooker. A pressure cooker, which is used for canning or other purposes, will save time in cooking soybeans for they soften very readily when cooked under pressure. When cooked thus, fill a quart jar with soaked beans, add 1 teaspoonful salt and half fill the jar with cold water. Cook one hour and a half at 15-lb. pressure.

Baked Soybeans, No. 1.

- 2 cups boiled soybeans
- 1 cup strained tomato pulp
- 1 tablespoon cornstarch
- ¼ teaspoon celery seed
- Dash of paprika
- 1 teaspoon onion juice
- 1½ teaspoons salt

Make a tomato sauce by mixing the cornstarch, celery seed, paprika, and onion juice with cold tomato pulp and cook until it thickens. Pour over the soybeans and bake in moderate oven until brown.

Baked Soybeans, No. 2

- 1 lb. of beans
- ¼ lb. of salt pork
- 1 teaspoon baking soda
- 2 teaspoons of molasses
- 1 teaspoon of mustard

Soak the beans over night in cold water. Pour off the water, and put beans in pot. Cover with cold water, add the soda, and cook gently until the beans are slightly softened. Pour off the water, mix the molasses and mustard with a pint of water and pour this over the beans, adding more water if the beans are not covered. Place the pork upon the beans, cover the vessel, and bring it to a boil. Then put in a fireless cooker and leave for 10 or 12 hours.

Baked Soybeans, No. 3.

- 1 qt. of soybeans
- 2 tablespoons molasses
- ½ teaspoon soda
- 1 teaspoon salt

Soak the beans for about 12 hours. Pour off the water, and cover with fresh water to which the soda has been added. Cook

just below the boiling point until tender. Pour off water. Put beans in a baking dish with salt and molasses, cover with boiling water, and bake slowly 3 to 4 hours. Keep covered except during the last hour.

Soybean Soup.

1 cup dry soybeans	1 teaspoon chopped onion
1½ cups canned tomatoes	½ teaspoon butter
1 teaspoon salt	1 tablespoon substitute flour
Paprika, pepper, water	

Soak beans in cold water 12 hours. Boil beans in water 4 hours, replenishing water as it boils away. Mash the boiled beans and put through a sieve. Saute the onion, add flour and blend. Add water and tomatoes, and other ingredients.

Soybean Vegetable Soup.

2 cups boiled soybeans	2 teaspoons onion juice
2 cups strained tomato pulp	¼ teaspoon pepper
2 cups water	1 teaspoon salt
½ cup chopped celery	1 tablespoon cornstarch

Cook the celery in the water until tender. Mix the cornstarch and seasoning with the cold tomato and add with the bean pulp to the celery and water. Cook 20 minutes.

Cream of Soybean Soup.

2 cups boiled soybeans	¼ teaspoon pepper
1 qt. skim milk	1 tablespoon cornstarch
1½ teaspoons salt	

Press the cooked beans through a colander. Mix the cornstarch with one-half cup cold milk. Heat the remainder of the milk in a double boiler with the soybeans, salt, and pepper. Add the cornstarch mixed with milk and cook for 20 minutes.

Soybean Croquettes, No. 1.

2 cups boiled beans	¼ teaspoon pepper
1 egg	2 oz. cheese
1 teaspoon salt	½ cup ground celery top and all

Grind the soybeans, cheese, and celery through a meat grinder. Add the salt, pepper, and one-half the egg, saving the remainder to use in crumbing the croquettes. Form into desired shape, roll in egg diluted with one-half tablespoon water, then in the corn meal, and bake in greased pan until brown.

Soybean Croquettes, No. 2.

1 cup soybean pulp
2 cups cooked rice
3 tablespoons chopped onion
1 tablespoon shortening
1 egg
½ cup corn meal
½ teaspoon salt
⅛ teaspoon pepper
¼ teaspoon kitchen bouquet
⅛ teaspoon paprika

Brown onion in shortening. Put 1 cup cooked soybeans through colander or food chopper. Add cooked rice and seasonings. Mold croquettes, dip slightly beaten egg, then in yellow corn meal. Bake in very hot oven, in shallow pans for about 30 minutes (until brown). Serve with tomato sauce.

Soybean Loaf. No. 1.

2 cups boiled beans
1 cup bread crumbs
1 cup chopped celery cooked until tender
1 tablespoon cornstarch
⅛ teaspoon curry powder
1 teaspoon salt
½ teaspoon pepper
½ cup milk

Mix the cornstarch, curry, salt, and pepper with the cold milk. Cook the mixture until it thickens, then mix with the soybeans (mashed or ground) and the other ingredients. Form into a loaf and bake in a greased pan.

Soybean Loaf, No. 2.

1 pt. cold boiled beans
1 cup bread crumbs
2 tablespoons tomato catsup
1 egg
1 tablespoon finely chopped onion
Salt and pepper

Run the boiled beans through a food chopper. Combine the ingredients. Form the mixture into a roll or loaf. Bake for about one hour.

Soybean Chili Con Carne.

Cut 1 lb. of round steak into small square pieces. Fry in hot fat until nicely browned. Then add cupful of boiling water. Cover, stew until tender. Add three red peppers, chopped fine. Add two cups of boiling soybeans, one medium sized onion chopped fine, one tablespoon of flour, four cloves, and a teaspoon of salt. Cook until gravy is of right consistency. Serve hot.

Soybean Roast.

1 cup grated cheese	Salt and pepper
1 cup mashed boiled soybeans	¾ cup water
1 cup bread crumbs	Juice of ½ lemon
2 tablespoons chopped onion	

Cook onion in butter and water until tender. Add beans, cheese, and bread crumbs, salt, pepper, and the grated rind and juice of a half of lemon. Turn into buttered baking dish. Cover with bread crumbs and dabs of butter and bake for 20 minutes.

Soybean Timbales.

1 cup bean pulp	Onion juice
1 cup milk	Salt, pepper
1 egg	Celery salt

Bake the mixture in buttered custard cups. Set in a pan of water until the mixture has thickened. Serve with tomato sauce.

Mexican Frijoles.

Soak 1 pt. of soybeans over night. Boil them for about 4 hours. Melt 2 tablespoons of fat in a frying pan; add the beans; cook them for 10 minutes. Serve with sauce made by the following recipe:

Frijole sauce.—Rub together 1 tomato, 5 green chilis (minced), 1 small onion (minced), one-half teaspoon salt, until they form a paste. Cook the mixture just long enough for it to become heated through.

Soybean Souffle.

½ cup bean pulp	½ teaspoon flour
½ tablespoon butter substitute	1 egg
2 tablespoons flour	½ cup milk

Melt butter substitute, add flour, add milk. Boil one minute, stirring constantly, add soybean pulp; cool; add beaten yolk of egg and seasoning. Beat white of egg until stiff; fold into mixture, and bake 30 minutes.

Soybean Pudding.

1 cup soybeans	Salt
2 cups bread or cracker crumbs	¼ cup honey
1 egg	Milk to moisten

Soak beans and boil until tender (general method of boiling). Press through fine wire sieve or run through food chopper. Salt to taste and let cool. To 2 cups of bean pulp add 2 cups bread or cracker crumbs. Moisten with milk, add egg well beaten. Sweeten with honey. Bake in moderate oven until light and brown. Serve with milk, fruit, or lemonaise.

Soybean and Fruit Pudding.

1½ cups bean pulp	3 tart apples
6 teaspoons lemon juice	¼ cup currants or raisins

To the bean pulp add salt to taste, and lemon juice, mixing well. Dice apples and mix with ¼ cup chopped currants or raisins. Shape pulp into balls dipped into the chopped apples and raisins, covering well. Serve on lettuce leaf with mayonnaise.

Soybeans and Macaroni.

2 cups soybean pulp	1 onion
2 cups boiled macaroni	1 tablespoon fat
2 cups canned tomatoes	Salt and pepper

Brown the onion, finely chopped, in fat. Add tomatoes, salt, and pepper. Let simmer for 20 minutes. Put through sieve. Put soybean pulp and macaroni in alternate layers in baking dish, cover it well with tomato sauce. Bake in moderate oven until brown.

Soybean Salad.

1 cup chopped boiled soybeans
1 cup celery chopped fine
½ cup American cheese

Combine and serve on crisp lettuce leaves; garnish with celery.

Soybean and Cottage Cheese Salad.

1 cup cooked soybeans
1 cup cottage cheese

Put the beans through the food chopper and season well with salt and pepper. Combine with cottage cheese. Serve on crisp lettuce leaves and garnish with strips of pimento.

Soybean Filling for Sandwiches.

1 cup soybean pulp	¼ teaspoon onion juice
1 teaspoon salt	⅙ teaspoon thyme
¼ teaspoon paprika	Dash of cayenne
1 teaspoon lemon juice	

Mix the ingredients together and serve as filling for sandwiches.

Soybeans and Rice.

1 pt. soybeans
2 tomatoes or 1 cup stewed tomato
2 teaspoons salt
1 cup rice
1 slice onion

Boil the beans. Cook the tomatoes with the onion. Strain, add the liquid in which the beans have been boiled. Add the salt and cook rice in this liquid, adding more water if necessary. When the rice is soft, combine with the beans and reheat.

Soybean Pastry.

1 cup flour
½ cup soybean pulp
½ teaspoon salt
2 tablespoons shortening
1 teaspoon baking powder

Moisten with cold water and roll out as ordinary pie crust. Avoid mixing too much. Fill with tart jam, jelly, or fruit. Bake 10 to 12 minutes.

Soybean Cookies.

½ cup flour
½ cup soybean pulp
2 teaspoons baking powder
1 egg
2 tablespoons fat
About ¼ cup milk
1 teaspoon fat
1 teaspoon lemon juice
3 tablespoons sugar or syrup

Cream sugar or syrup with the fat. Add the soybean pulp into which the salt has been worked. Add the milk, the egg well beaten, the sifted flour and baking powder. Drop by spoonfuls on a greased pan and bake in a rather hot oven 12 to 15 minutes.

Soybean Crust.

1 cup boiled soybean pulp
½ teaspoon salt
2 tablespoons melted fat
1 teaspoon baking powder
1 egg (beaten)

Combine the ingredients and add enough flour to make a soft dough. Roll out the mixture to about ⅛ in. in thickness on a well-floured board. Cut strips of suitable size to fold for individual pies. Fill the pies with chopped cooked meat or vegetables. Fold the crust over and press it together along the edges. Bake the pies in a moderate oven until they are well-browned.

Soybean Muffins.

2 eggs (well beaten)	1 teaspoon salt
1 cup cold boiled bean pulp	2 cups flour
½ cup milk	2 teaspoons baking soda
⅓ cup melted fat	

Combine the ingredients in the order given. Bake in a greased muffin pan for 20 or 25 minutes. These muffins make a good border for a pot roast, served with brown gravy.

Soybean Flour.—An almost endless series of dishes can be made from soybean flour. In using this flour, it should be remembered that it is rich in protein and fat and should be combined with starchy substances like rice, potatoes, or corn flour. As soybean flour contains considerable fat, not much shortening is required.

Soybean Bread.—Soybean bread may be made by substituting soybean flour for ¼ of the wheat flour in the ordinary bread recipe. This will give a bread of good texture, light brown interior and a dark brown crust. This bread should bake more slowly and for a longer time than the wheat-flour bread.

Soybean Biscuits, No. 1.

1 cup soybean flour	½ teaspoon salt
1 cup wheat flour	½ to ⅔ cup water
4 teaspoons baking powder	

Bake 15 minutes.

Soybean Biscuits, No. 2.

½ cup wheat flour	5 teaspoons baking powder
¼ cup soybean flour	Salt
1½ tablespoons fat	Milk

Mix the dry ingredients and sift twice. Work in shortening with tips of fingers. Add gradually the liquid, mixing with knife to soft dough. It is impossible to state the exact amount of liquid owing to differences in the flour. Put on a floured board and roll lightly to ½ in. thickness. Shape with biscuit cutter. Place on greased pan and bake in hot oven 12 to 15 minutes.

Soybean Muffins, No. 1.

1 cup soybean flour	4 teaspoons baking powder
1 cup corn, rice, or potato flour	2 tablespoons corn syrup
1½ cups liquid	1 teaspoon salt
1 egg	

Bake slowly in moderate oven for 30 minutes.

Soybean Muffins, No. 2.

1 cup soybean flour
1 cup mashed potatoes or cooked rice
1 cup liquid
1 egg
4 teaspoons baking powder
2 tablespoons corn syrup
1 teaspoon salt

Bake slowly in a moderate oven for 30 minutes.

Soybean Muffins, No. 3.

1 pt. soybean flour
1¾ cups fresh buttermilk
1 egg
½ teaspoon soda
½ teaspoon salt

Bake as other muffins.

Soybean Muffins, No. 4.

1¼ cups wheat flour
¼ cup soybean flour
½ teaspoon salt
2 eggs
1 cup sweet milk
2 rounded teaspoons baking powder
1½ tablespoons melted butter

Beat the ingredients well together, adding the melted, but not too hot, butter last, and bake in gem pans in a hot oven.

Persons desiring a food of low starch content should take in the above recipe 1¼ cups soybean flour and ¼ cup of wheat flour.

Soybean Muffins, No. 5.

2 eggs
1½ cups milk
1 cup soybean flour
½ teaspoon salt
2 teaspoons sugar
2 teaspoons baking powder
2 tablespoons melted fat

Sift dry ingredients, add milk gradually, beat eggs thoroughly, add melted fat and put in greased muffin tins. Bake in hot oven.

Soybean Griddle Cakes, No. 1.

1 cup soybean flour
1 cup corn flour
3 cups liquid
4 teaspoons baking soda
1 teaspoon salt
2 eggs

Soybean Griddle Cakes, No. 2.

1 cup soybean flour
1 cup buckwheat flour
1 cup wheat flour
3 cups liquid
4 teaspoons baking soda
1½ teaspoons salt
2 eggs

Soybean Coconut Pudding.

3 tablespoons shortening
1 cup brown sugar
½ cup milk
½ cup shredded coconut (steamed until moist)
¾ cup soybean flour
¼ cup wheat flour
¼ teaspoon salt
3 eggs beaten separately
1½ tablespoons baking powder

Cream the shortening and brown sugar, add egg yolks well beaten, then add alternately the milk and sifted dry ingredients. Have the coconut prepared, and add with the last of the flour. Beat well, then add beaten egg whites, turn into well-oiled spout cake pan and bake in a moderate oven until it shrinks from sides of pan. Serve hot or cold with Lemon Pudding Sauce.

Soybean Spice Cake.

¼ cup shortening
1 cup brown sugar
½ cup molasses
3 eggs beaten separately
¾ cup soybean flour
1½ cups wheat flour
3½ teaspoons baking powder
½ teaspoon salt
1 teaspoon cinnamon
½ teaspoon cloves
½ teaspoon nutmeg
1 cup raisins
½ cup milk

Cream the shortening and sugar, then add molasses, then egg yolks beaten until thick and lemon colored. Mix and sift the dry ingredients, adding them alternately with the milk, stirring the raisins in with a part of the flour. Beat well, then add stiffly beaten egg whites and bake in a greased tube cake pan in a moderately slow oven until it shrinks from the sides of the pan.

Soybean Mush.

1 cup soybean flour
1 teaspoon salt
3 cups water

Cook in a covered double boiler for 2 hours. When cold it can be sliced, rolled in corn flour, and fried in drippings.

Soybean Croquettes (Mush).

1 cup soybean mush
1 cup cooked rice
1 egg
1 teaspoon grated onion
1 teaspoon salt
¼ teaspoon pepper
2 tablespoons chopped salt pork

Shape into croquettes, roll in egg and corn meal or flour, and bake in oven.

Soybean Loaf (Mush).

1 cup chopped meat	2 tablespoons chopped onion
1 cup soybean mush	1 tablespoon dried celery leaves
2 cups mashed potatoes	2 teaspoons salt

Combine the ingredients, bake as a loaf for one-half hour or shape into small cakes and fry in drippings.

Soybean Omelet.

2 eggs	2 tablespoons cooked rice
2 tablespoons milk	¼ teaspoon salt
3 tablespoons soybean mush	

The advantage of this omelet is that a larger and more nutritious omelet is made by the use of soybean flour and rice.

Soybean Fruit Cake.

3 cups soybean flour	1 nutmeg grated
½ cup butter	2 teaspoons mixed spices
2 cups sugar	2 teaspoons baking powder
4 eggs	2 teaspoons cinnamon
1 pound seeded raisins	½ cup wine

Soybean Gems.

1 egg	¼ teaspoon salt
1 tablespoon cream	½ teaspoon baking powder
2 tablespoons soybean flour	

This recipe makes four gems and will be found especially desirable for persons requiring a food of low starch content.

Soybean Spoon Bread.

½ pt. soybean flour	½ teaspoon salt
1 pt. fresh buttermilk	½ teaspoon soda
1 egg	1 teaspoon sugar
1 tablespoon melted butter	

Soybean Wafers.

1¼ cups wheat flour	½ teaspoon salt
¾ cup soybean flour	2 tablespoons butter
2 teaspoons vanilla	2 tablespoons lard
¼ cup milk	2 teaspoons baking soda
1 egg	1 cup sugar

Cream butter, add sugar, well beaten egg, milk, and vanilla. Mix dry ingredients and add to first mixture. Roll as thinly as possible, cut, and bake in a moderate oven.

Soybean Jam Pudding.

½ cup brown sugar
⅓ cup corn syrup
3 beaten eggs
½ cup sour milk
½ teaspoon soda
1½ cups soybean flour
1½ teaspoons baking powder
⅓ cup finely chopped suet
¾ teaspoon salt
½ teaspoon cinnamon
1 cup strawberry, blackberry or raspberry jam

Cream the sugar and syrup. Beat together the eggs, soda, and sour milk, add about half to first mixture, then stir in suet; then add alternately the balance of sour milk mixture, sifted dry ingredients and jam. Turn into well-oiled pudding dish or spout cake pan and bake in moderate oven about 40 minutes. Serve hot with pudding sauce or cold as cake.

Soybean Ginger Cookies.

½ cup vegetable shortening
½ cup corn syrup
1 cup brown sugar
2 beaten eggs
2 tablespoons milk
3 cups soybean flour
1 teaspoon ginger
½ teaspoon salt
1½ teaspoons baking powder
1 teaspoon vanilla

Melt shortening and add syrup and brown sugar. Bring to boil, chill thoroughly. Beat the eggs and add to them the milk and vanilla and stir into first mixture. Mix and sift the flour, ginger, baking powder, and salt and work in. Roll on floured board very thin. Cut with cookie cutter and bake in hot oven.

Soybean Gingerbread.

⅓ cup vegetable shortening
1 cup brown sugar
2 beaten eggs
3 tablespoons molasses
Pinch of soda
1 cup soybean flour
2¼ cups wheat flour
½ teaspoon salt
1 tablespoon ginger
2 tablespoons baking powder
½ teaspoon cinnamon
1¼ cups milk

Cream the shortening and brown sugar; add beaten eggs, then the mixed molasses and soda. Mix and sift the balance of dry ingredients and add alternately with the milk. Beat well, turn into an oiled shallow baking pan and bake in a moderately hot oven.

Soybean Filled Cookies.

½ cup vegetable shortening
½ cup corn syrup
½ cup brown sugar
2 beaten eggs
½ cup milk
½ teaspoon vanilla
1½ cups soybean flour
2½ cups wheat flour
1 teaspoon salt
1 teaspoon baking powder
½ teaspoon nutmeg
½ teaspoon ginger
½ teaspoon cinnamon

Cream the shortening, sugar, and syrup. Add well-beaten eggs, then add alternately the milk and flavoring with the sifted dry ingredients. Have ready the following filling and when filling is cool, roll dough thin, cut with cookie cutter and spread between each two cuts some of the filling. Press edges together slightly and bake in a moderately hot oven.

Filling: 1 cup seeded or seedless raisins, ½ cup corn syrup, ¼ cup strained honey and 2 tablespoons water. Boil until it begins to thicken, then cool.

Soybean Yeast Raised Coffee Cake.

1 cup scalded milk (cooled)
1 tablespoon sugar
½ teaspoon salt
½ cake of yeast dissolved in ¼ cup lukewarm water
1 cup soybean flour
3 cups wheat flour
½ cup sugar
1 egg or 1 teaspoon egg substitute
¼ cup shortening

Make a sponge of the milk, sugar, salt, bean flour and one cup of wheat flour. Add the dissolved yeast and let the mixture stand over night. Then add the other two cups of flour and the shortening, sugar and egg. Place in shallow pans and let rise until very light. When ready to bake, rub the tops with sugar dissolved in milk and sprinkle with dry sugar and cinnamon. Bake about 25 minutes. A few raisins may be added to the dough if desired.

Soybean Soft Ginger Cake.

½ cup melter shortening
1 cup syrup
1 teaspoon cinnamon
1 cup sour milk
1 teaspoon sŏda
½ teaspoon clove
1 cup soybean flour
3 cups white flour

Beat to a smooth batter. Pour into a well greased and floured pan. Bake in a moderate oven for 40 minutes.

Soybean Nut Bread.

1½ cups soybean flour
1½ cups white flour
⅔ cup dark brown sugar
1½ teaspoons salt
2½ teaspoons baking powder
2 cups buttermilk or sour milk
1 teaspoon soda
1 cup nut meats

Sift flour and mix with sugar, salt and baking powder. Stir soda into the buttermilk and briskly stir all together, adding the nut meats last. Form in a loaf and bake in a moderate oven 40 to 45 minutes.

Soybean and Rye Bread.

2 cups soybean flour
4 cups rye flour
1½ teaspoons salt
1 tablespoon brown sugar
2 tablespoons shortening
2 tablespoons baking powder
1½ cups milk and water

Sift dry ingredients together. Add the milk and water and melted shortening. Beat thoroughly and put into a well-greased pan and stand in a warm place for 30 minutes. Bake in a moderate oven 45 minutes.

Soybean Cup Cakes.

¾ cup soybean flour
¾ cup white flour
½ cup milk
1 egg
½ cup sugar
2 tablespoons butterine
3 teaspoons baking powder

Cream butterine and sugar together; add the egg. Sift flour and baking powder together and add to the creamed butterine, mixing in a little milk at a time and beating well together for 5 minutes. Bake in a moderate oven 20 to 25 minutes.

Soybean Pancakes.

2 tablespoons soybean flour
2 tablespoons white flour
1 egg or 1 teaspoon egg substitute
1 teaspoon baking flour
1 teaspoon salt

Mix all together with a little milk or half milk and water, to a creamy batter. Fry on a hot skillet.

Soybean Flour and Celery Soup.

1 stalk celery
1 tablespoon butterine
1 pt. water
2 tablespoons soybean flour
1 tablespoon white flour
1 teaspoon salt

Cut celery very fine and boil in sufficient salted water to leave 1 pt. when cooked, add the soybean flour before the celery is entirely cooked and allow to simmer. Blend the white flour with the butterine and when the celery is soft add together, simmer for one minute and serve.

Tofu.—Attempts have been made during the past 5 years to introduce tofu to the American people, but without much success. In cities having a large oriental population fresh tofu or bean curd may be had at the Chinese stores. The following recipes prepared by the Soy Products Co., and Chicago Bean Bread Co., indicate the wide adaptability of tofu, or soy cake as it is termed by one company, to all kinds of cooking, and at the same time may suggest other practical ways in which this valuable food may be prepared.

Chicken Soy Cake (Tofu).

¼ lb. soy cake	½ level teaspoon salt
1 cup thinly sliced celery	¼ level teaspoon pepper
1 pt. chicken stock	¼ level teaspoon paprika
1 small onion	2 tablespoons flour
1 bay leaf	1 tablespoon chicken fat, butter or lard
1 cup diced or shredded chicken	

Heat the fat. When hot, put in the celery and onions. Cover and salt until they turn color (do not brown), stirring with a fork occasionally to prevent burning. Covering preserves the flavor and prevents turning color too soon. About 10 minutes should be sufficient. Then add the cold stock, soy cake (tofu), chicken and seasonings. Simmer gently from 20 to 30 minutes. Thicken with flour and water and serve with rice. This makes 1½ pt. When used again, reheat in a double boiler. Other meats and combinations may be prepared in the same way.

Soy Cake (Tofu) with Tomatoes.

½ lb. soy cake	2 tablespoons lard
1 qt. canned or stewed tomatoes	2 tablespoons flour
1 large onion thinly sliced	Pepper and salt to taste
1 cup thinly sliced celery	

Put into a saucepan the lard and when hot add the celery and onion. Cover and saute till they commence to turn color (do not brown), stirring with a fork occasionally to prevent burning. Then add the tomato (cold) and when hot add the soy cake and seasonings. Simmer very gently from 20 to 30

minutes. Thicken with the flour dissolved in a little cold water, and serve. More onion may be added if desired, and if the tomatoes are very solidly packed it may be necessary to add a little water to make enough sauce. This makes 1½ qt.

Soy Cake (Tofu) with Tomatoes and Cheese.

1 pt. canned or stewed tomatoes
1 cup boiled rice
2 stalks celery sliced very thin diagonally
½ onion cut fine
¼ lb. soy cake cut in pieces ¼ in. thick
¼ green pepper cut in pieces
½ cup cheese cut fine
Season to taste

Mix the ingredients cold. Heat in a saucepan from 20 to 30 minutes. Then put in a baking dish. Sprinkle with bread crumbs and brown very quickly in a very hot oven or under the bar of a gas range.

Mushrooms with Soy Cake (Tofu).

½ lb. soy cake
¼ lb. mushrooms
1 pt. milk
1 small onion thinly sliced
2 tablespoons butter
2 tablespoons flour
Pepper and salt to taste

Heat in butter in a saucepan; then add the celery and onion. Cover and saute till they commence to turn color (do not brown), stirring with a fork occasionally to prevent burning. Add the milk and stir till hot; then add mushrooms, soy cake and seasonings. Transfer to a double boiler and cook for one half-hour. Thicken with the flour dissolved in a little cold water and serve in paper or pastry shells. This makes about 1 qt.

Potatoes with Soy Cake (Tofu).

½ lb. soy cake
4 cups diced raw potatoes
1 large sliced bacon minced fine
1 large onion sliced thin
2 tablespoons bacon fat or lard
2 tablespoons flour
Pepper and salt to taste

Saute the bacon, onion and potatoes together till they commence to turn color (do not brown) stirring with a fork occasionally to prevent burning. Cover with cold water and cook one half hour. Add the seasonings and soy cake and keep hot (do not boil) 20 to 30 minutes. Thicken with flour dissolved in a little cold water, and serve. This mixture may also be put in a baking dish when the soy cake is added, and browned in a hot oven.

This recipe may be varied by using equal parts of potato, celery, onion and carrot.

Soy Cake Stuffed Peppers.—Use left-over fish which is already cooked. Pick the fish into small pieces. Add some soy cake (tofu) and a little boiled rice. Season to taste, stuff in green peppers or tomatoes and brown in a hot oven. The soy cake for this fish may be chopped or mashed with a fork and the proportions may be made to suit the taste or convenience.

Cabbage or Cauliflower Soy Cake (Tofu).—Allow about 2 oz. of soy cake per person. Shave the cabbage as for cold slaw or break the cauliflower into small pieces. Cover with cold water and bring to a boil. Add the soy cake, season to taste and cook slowly about 30 minutes. Thicken with flour dissolved in a little cold water and serve.

Eggs a la Caracas with Soy Cake (Tofu).

1 cup soy cake cut in ¼ in. pieces
1 cup tomatoes
¼ cup grated cheese
Few drops onion juice
Few grains cinnamon, cayenne
2 tablespoons butter
3 eggs

Melt butter. Add soy cake, tomatoes, cheese, onion juice, cinnamon and cayenne. Heat from 20 to 30 minutes. Add eggs well beaten. Cook until eggs are of creamy consistency, stirring and scraping as in scrambled eggs.

Soy Cake (Tofu) with Tuna Fish.

¼ lb. soy cake
¼ small can tuna fish
1 cup milk
½ cup thinly sliced celery
½ small onion thinly sliced
1 tablespoon butter
1 tablespoon flour
Pepper, salt and paprika to taste

Heat the butter in a saucepan, and when hot add the celery and onion. Cover and saute until they commence to turn color (do not brown) stirring with a fork occasionally to prevent burning. Then add the milk and tuna fish and bring to a boil, stirring constantly. Add the soy cake and seasonings and transfer to a double boiler. Cook for 30 minutes. Thicken with flour dissolved in a little cold water and serve. This makes enough for two people.

Soy Chicken Salad.—Cut the soy cake (tofu) in thin, narrow strips, put into cold chicken stock and heat from 20 to 30 minutes. Allow the soy cake to remain in the stock until cool

in order to absorb flavor. Then remove and use in salad as shredded chicken, with a little real chicken added.

Soy Cake (Tofu) Salad Dressing.—Mash the soy cake with a fork and mix with oil and vinegar dressing, mayonnaise, or any other desired salad dressing. Allow to stand 30 minutes before using. Mayonnaise dressing can be made to go farther at less cost if mixed with soy cake.

Salted Tofu.—An easy method of salting tofu ready for any use, in hot or cold dishes, is to place the amount needed in cold water, with two tablespoons of salt to a pound of tofu. Bring slowly to the boiling point. Remove from the fire and allow to cool.

Tofu for Soup.—Tofu will be found a nutritive and palatable addition to any kind of soup. It may be mashed or diced.

Tofu and Fish.—Boil two stalks of celery (cut very fine) with a tablespoon of minced parsley in two cups of boiling water. When the celery is cooked thicken it with a tablespoon of egg substitute and add one teaspoon of butter. Dice very fine one-half pound of tofu and with a small can of any kind of fish add to the creamed mixture. Garnish dish with parsley and serve.

Tofu with cheese.—Prepare a small amount of cream sauce to which add ¼ lb. of grated cheese. When this is thoroughly dissolved and blended, add 1 lb. of diced, salted and cold tofu and ¼ lb. of bean sprouts. Mix well and place in a casserole. Cover with cracker crumbs and dot with butterine. Bake until set.

Creamed Tofu in Ramekins.

1½ cups salted tofu (½-in. cubes)
½ cup mushrooms (½-in. cubes)
2 tablespoons butterine
3 tablespoons corn flour
1½ cups milk or meat stock
⅛ teaspoon celery salt
⅛ teaspoon paprika
1 teaspoon salt
2 teaspoons mushroom ketchup
1 tablespoon butterine
1 cup bread crumbs

Heat the fat in a pan thoroughly. Then add the corn flour and next the liquid, making a sauce. Season and add the tofu and mushrooms. Place in greased ramekins; cover with the bread crumbs which have been stirred into a tablespoon of butterine. Bake in a hot oven 15 or 20 minutes. Serve with a slice of lemon.

Tofu and Vegetable Stew.

2 heads of celery	2 good-sized onions
1 tablespoon kitchen bouquet	¼ lb. bean sprouts
2 tablespoons flour	1 tablespoon butterine
1 lb. tofu	Salt and pepper to taste

Cut the celery into 1 in. lengths, also cut up the onion and boil until soft in 1 qt. of water, to which salt and pepper have been added. Wet the flour with the kitchen bouquet and melted butterine, and pour into the celery and water it was boiled in. Cut the tofu into small strips or dice and add the thickened vegetables. Then have the bean sprouts well washed and drained and put them in last. Season to taste and boil 5 minutes. Serve in tureen as Irish stew.

Tofu and Bacon.—Split salted tofu and place in a baking dish. Put two thin slices of bacon on top and crisp in a hot oven.

Pickled Tofu.—Cut in half two cakes of tofu and stick two cloves in each part. Sprinkle with salt and a teaspoon of sugar. Place on the fire ½ pt. of vinegar, one good-sized onion, one-half teaspoon whole mixed spices (tied in a bag) and boil for 2 minutes. Remove spice bag and set to cool before pouring over tofu. One cup of bean sprouts added will be an improvement.

Tofu Cakes.—Mash sufficient warm salted tofu to make three cups. Add one cup of sausage or ground left-over meat (in using left-over meat be sure to season it). Make into small cakes, dip into cracker crumbs or corn meal and fry quickly in hot fat.

Curried Tofu.

1 lb. tofu (diced)	1 teaspoon curry powder
2 tablespoons oleomargarine	1 chopped onion
1 tablespoon flour	1 cup strained tomatoes
1 teaspoon salt	¼ teaspoon white pepper

Put one-half of the oleomargarine in the frying pan and in it cook the onion slowly without browning until it is soft. Add the curry powder and tofu, and shake the pan over a quick fire for 2 minutes. Place the other half of the oleomargarine in another frying-pan, and when hot add to it the flour. Stir well, then add the salt, pepper and tomatoes. Let come to a boil and then pour over the tofu in the other pan. Cover and cook slowly for 3 minutes. Boiled rice makes a nice addition to be served with this dish.

Tofu in Pineapple Jelly.

1 packet gelatine	½ lb. salted tofu
1 cup crushed pineapple	1 pt. water
½ cup sugar	

Boil sugar and pineapple in water until sugar is entirely dissolved. Stir in the gelatine and when thoroughly dissolved, add the salted tofu (diced). Place in a mold and allow to set in a cool place for 5 hours. This is delicious served with whipped cream.

Soybean Sprouts.—Soybean sprouts are especially valuable as a green vegetable and on account of their high nutritive value. The sprouts are easily prepared, have no waste, are quickly prepared, not more than 4 or 5 minutes in any given way. Boiling water should be poured over the sprouts before using for soups, stews, fried or boiled and creamed.

Fried Sprouts.—After frying any kind of meat, make a thick gravy. Have the sprouts cleansed and place in the skillet with a little salt. Stir about and cook for 3 to 5 minutes according to amount used. These are delicious with steaks or chops.

Creamed Sprouts.—Prepare a cream sauce as for carrots or any other vegetable. Cleanse the sprouts and add to the sauce. Simmer in double boiler for 5 minutes and serve.

French Sprout Salad.—Cleanse 1 lb. of sprouts and put in cold water to chill. When thoroughly drained, sprinkle with a little salt and pour over them a French dressing made as follows: Rub a soup plate with clove or garlic, or cut an onion; put in half a level teaspoon of salt, one-eighth teaspoon of paprika and then add one tablespoon of olive oil, stirring briskly until the salt is dissolved; then add two tablespoons of vinegar, stirring constanty.

Spanish Salad.—Prepare 1 lb. of sprouts as for French Sprout salad. Add one small Spanish onion finely chopped, one cup of chopped celery and one sweet pepper minced very fine, or one pimento. Stir all together with a mayonnaise dressing which will require plenty of salt in it, or salt the vegetables a little first. Leave a little mayonnaise to spread on top. Garnish and serve.

Potato Salad.—A few bean sprouts added to a potato salad will be found a delicious and appetizing addition.

Sardine Salad.—Parboil one stalk of celery and one small onion together in 1 pt. of water. When cooked thoroughly, drain and mash into it one small box of sardines, first draining off the oil.

Prepare some sprouts with a French dressing and serve on lettuce leaves.

Fruit Salad.—A delicious fruit salad is made by taking equal parts of bean curd (first cut into dice), orange, pineapple, and a few nut meats added. Make a nest of bean sprouts and pour over the whole a French dressing and serve.

Chicken Salad.—Prepare a chicken salad in the usual way. Add one cup of diced bean curd and one of bean sprouts. This will be found a decided improvement.

Fish Salad.—Take one cup of any kind of left over fish to 1 lb. of bean curd and with salt and pepper to taste, mash together (a little finely minced parsley or onion may also be added). When thoroughly mixed, add ½ lb. of bean sprouts (prepared for salad). Mix together with a little French dressing, garnish with lemon and cucumber and serve.

CHAPTER XV

ENEMIES OF THE SOYBEAN

As yet no pest has assumed any great economic importance with the culture of the soybean in America. According to Hemmi (1915) there are many destructive diseases which attack the soybean in Japan and of which investigations have been made to a greater or lesser extent. There seem to be no available data concerning pests of the soybean in China or Manchuria. It would seem that the soybean is less affected by destructive diseases and insects than are most other forage or food plants.

Bacterial Diseases.—Several bacterial diseases of the soybean have been described apparently three or four of which are caused by different organisms. None has as yet caused large damage.

A bacterial blight of the leaves of the soybean was noted by Heald (1906) at the Nebraska Experiment Station in 1904 and it is stated that in 1906 this disease was quite serious on soybeans used as an orchard cover crop.

Clinton (1915) of the Connecticut Experiment Station in 1915 found a bacterial disease in soybean leaves which was apparently identical with a somewhat similar appearing leaf-spot on lima and wax beans. On the soybeans the spots were generally dark reddish brown about 1 to 2 mm. in diameter, with a somewhat irregular outline. Very often a yellowing of the tissues outside the spots is seen.

Johnson and Coerper (1917) report having a bacterial blight of the soybean under investigation at the Wisconsin Experiment Station. Later, Coerper (1919) describes the morphological and cultural characters and gives a technical description of the organism, *Bacterium glycineum* n. sp. This blight is considered the same as that reported from various parts of the United States. It is characterized by the appearance on the leaves of small angular spots which are either isolated or confluent. In late stages, the diseased tissues become dry and drop out, giving the leaves a ragged appearance. Among its most serious characteristics is that it is a seed-borne disease. Under favorable moisture condi-

tions, it is spread rapidly from the point of original infection to adjacent plants.

Woodworth and Brown (1920) in studies on varietal resistance and susceptibility to bacterial blight of soybeans at the Wisconsin Experiment Station, found that field experiments indicated that soybean varieties vary greatly in their relative susceptibility to the bacterial blight. Of forty-seven varieties grown in 1918 about one-half were completely resistant, and the other half ranged from complete susceptibility to partial resistance.

A bacterial blight of soybeans in North Carolina is described by Wolf (1920), which was said to have been first reported in Nebraska in 1905 and later in Connecticut, Wisconsin and North Carolina. The infection is believed to spread from the cotyledon to the true leaves and from these to other leaves. The cause of the blight is said to be *Bacterium sojæ* n.sp. The disease is considered to differ in several respects from the one previously described as due to *Bacterium glycineum.* Infected seeds are believed to be the chief means by which the disease is carried over winter and by which it is introduced into new localities. Infected leaves which remain in the field during winter have been found to harbor the parasite.

Takomoto (1921) calls attention to a bacterial spotting disease of the soybean in Japan which is said to be caused by a new bacterium not identical with *B. glycineum*, *B. soyæ*, or *Pseudomonas glycineum* Nakano.

In a discussion of parasitic and so-called symbiotic relationships, Van der Wolk (1916) gives an account of a soybean disease in which, appearing first as an etiolated condition, may result in the death of the plant. The trouble appeared to be due to the activities of the bacterium (*Rhizobium beyerinckii*) associated with the root nodules, which are here compared with plant galls.

Mosaic Disease.—In 1915 Clinton (1915) found a mosaic disease of soybeans at Mount Carmel, Connecticut. The disease is described under the name of *chlorosis* or *crinkling* and was found on Medium Green, Wilson, Swan, Kentucky, Mikado, and Midwest varieties, of which the Midwest showed the most marked symptoms. The chlorosis without the crinkling was found on the Okute, Ito San and Manhattan varieties. Gardner and Kendrick (1921) found a typical mosaic disease in 1920 in a small field of Hollybrook soybeans at West Lafayette, Indiana. A rather low percentage of the plants were affected, and the

disease was more or less confined to one quarter of the field adjacent to which were several rows of garden beans affected with mosaic to a considerable degree. The symptoms of soybean mosaic were conspicuous and unmistakable, resembling those characteristic of mosaic diseases in general. The mosaic affected plants were stunted, and the petioles and internodes were shortened to some extent. The leaflets were stunted, greatly misshapen, and puckered with dark green puffy areas along the veins. Between these puffy areas the leaf tissue was etiolated. The young, rapidly growing leaves showed the most severe effects, and in some cases whole leaflets or portions thereof were extremely stunted or killed outright by the disease. The pods on mosaic plants were stunted and flattened, less pubescent, and more sharply curved than those on normal plants. Those borne at the upper nodes were more severely affected. The yield of seed was very materially reduced, since a considerable proportion of the pods contained no viable seeds, and the remainder as a rule not more than one or two good seeds which were in general undersized. Observations showed that the mosaic plants remained green longer than the normal plants. Orton (Fromme, 1921) reports the occurrence of mosaic in a field of Ito San soybeans at Girard, Pa., in 1920. Soybean mosaic was reported at Oxford, North Carolina in 1920 by Wolf and Lehman (1920).

Fungous Diseases.—Several different fungous diseases are known to attack the soybean in the United States, and one is described from Japan.

Fusarium Disease.—A disease in North Carolina due to *Fusarium tracheiphilum* is described by Cromwell (1917). The disease, characterized by chlorosis and shedding of the leaves or leaflets, followed by the death of the plants, is termed blight or wilt. It has been observed in several localities in North Carolina on soils infected with cowpea wilt. Cultural and morphological studies, as well as reciprocal inoculation experiments, have shown that the two diseases are caused by the same species of Fusarium. Infection is thought to occur through the roots, but the presence of nematodes does not appear to increase the percentage of blight. The character of the soil is considered to influence the amount of infection, the largest proportion of diseased plants occurring on coarse sandy soils. In later studies on this disease concerning the relation of various factors to infection, Cromwell (1919), found that the physical structure

and acidity of soils under natural conditions were not limiting factors in infection, but acidity under certain conditions was found to have some influence.

Rhizoctonia and Sclerotium rolfsii, and other root injuries are believed to increase materially the percentage of diseased plants in the field. In investigations on the susceptibility of different varieties of soybeans, the Black Eyebrow variety was found to show resistance. The Mammoth Brown variety, while not resistant, appeared tolerant and developed remarkably in spite of numerous fungus filaments and nematodes within the roots. Fifteen other varieties tested were found to be severely affected.

The Fusarium disease of the soybean is carried by the same fungous that engenders wilt of the cowpea.

Phoma Disease.—In the North Carolina Experiment Station soybean breeding garden, certain of the early maturing varieties were noted by Wolf and Lehman (1920) to be affected with a blight which involved the stems and pods. At first isolated plants only were diseased, but the infection gradually involved others. A species of Phoma, as yet undetermined was fruiting in abundance upon the affected parts. Previously no species of Phoma was known to occur on the soybean.

Septoria Disease.—A new brown spot disease of the leaf of the soybean plant in Japan caused by *Septoria glycines* n. sp. is described by Hemmi (1915). Investigations showed that the disease was very common throughout the different parts of Japan. The disease is characterized by enlarging spots appearing on both surfaces of young leaves, which become discolored and fall, the disease working toward the top of the plants and often ruining the entire crop. It spreads most rapidly in damp warm weather and in places which are poorly drained. In a dry season or place the disease is checked so that the upper leaves are usually not attacked, but if the favorable conditions set up, the disease spreads again actively. Although this disease may not cause complete loss of the crop, it may interfere with general productiveness by diminishing its assimilating power.

Anthracnose.—In North Carolina, Wolf and Lehman (1920) found a number of soybean plants whose pods bore lesions which were encrusted with conidia of a fungus belonging to the genus Colletotrichum. The organism was identified as that of anthracnose, *Glomerella cingulata.* This occurrence of *G. cingulata*

on soybean is of interest since only one other legume, the sweet pea, is known to be attacked by it.

Rot.—This disease is caused by a fungus, *Sclerotium rolfsii* that forms pinkish round bodies on the roots as large as a pea. The root dies and the whole plant gradually succumbs. Thus far the disease has not been very serious, but in some fields about 5 per cent. of the plants have been killed. It has been noted in southern Mississippi.

Nematode Disease.—Two different nematodes cause injury to the roots of soybeans and reduce the crop considerably.

Rootknot.—Rootknot caused by the nematode (*Heterodera radicicola*) often causes considerable injury to soybeans in many parts of the southern states where this pest is prevalent (Fig. 84). In sections where the pest has become well established in the soil, only varieties of soybeans resistant to the nematode should be planted. To plant susceptible varieties is a dangerous practice, not only because the bean crop will be reduced, but also because the pest can propagate freely and greatly damage any susceptible crop which follows the soybeans. The Laredo and three other unnamed varieties have been found highly resistant both to nematode and to wilt.

Yellow Dwarf.—A disease in Japan caused by the nematode (*Heterodera schachtii*) is mentioned by Katsufuji (1919) and named Yellow Dwarf. This nematode also occurs in the United States.

Insects.—Insect enemies of the soybean are numerous enough, but thus far have not been an important factor in the culture of the crop. The Mexican bean-beetle, however, seems likely to be a serious menace.

Leaf Hopper.—Ainslee reported in 1908 that he found soybeans infested with a green leaf hopper at the South Carolina Experiment Station. The leaf hoppers were present in great numbers in all stages and many of the leaves were corrugated by them. The lower leaves were yellowish, and when the plants were disturbed the hoppers flew out in clouds. Specimens of these were identified as *Empoasca mali.* According to Osborn (1912) the two most important species of leaf hoppers working on the soybean plant are *Agallia sanguinolenta* and *Empoasca mali.* At the Indiana Experiment Station it was found that the life history of *Empoasca mali* was based on the soybean crop as several larvæ and a few adults were found.

Thrips.—Okamato (1909–10) describes a new species of insect,

Liothrips glycinicola, which is commonly found in the flower of the soybean plant in Japan. According to the investigations of different Japanese agriculturists, the pollen grains are apparently much damaged by this insect.

FIG 84.—Root of a soybean plant showing rootknot caused by the nematode (*Heterodera radicicola*).

In the authors' investigations of the soybean, thrips were observed as very common in the soybean flower at Arlington Farm, Virginia. So far the evidence indicates that the thrips are

not appreciably injurious in their influence upon the development of soybean seed. It is quite evident that these insects feed upon the pollen and the cellular tissue of the flower.

Legume-pod Moth.—In some sections of California, the legume-pod moth (*Etiella zinckerella schisticolor*) has been found to attack the soybean. In one variety test the earlier varieties seemed more susceptible to the attacks of this insect than others. As this insect is readily controlled by preventive measures, it is not likely to assume any importance as a serious pest to the soybeans.

Soybean Stem-borer.—With the introduction of the soybean on an experimental scale at Sabour, India, a cerambycid beetle of the genus *Nupserlia*, appeared and became a source of serious damage. An account is given by Dutt (1915) of the life history and habits of this insect, together with recommendations as to the prevention of injury and remedial measures.

Chinch Bugs.—Reports have been received at various times from different parts of the corn belt as to the effect of soybeans on chinch bugs. Long (1914) had his attention called to the fact that corn planted on one side of a wheat field which was badly infested with chinch bugs was not bothered while that on the other side of the same field was nearly destroyed. The only difference between the two fields was that the first had soybeans in it and the other did not. In another instance a stubble field where the wheat had been badly infested was broken up and planted to corn and soybeans. In a number of hills the beans failed to come. Those hills were destroyed by the bugs, and the hills where the beans came were practically unhurt. A badly infested rye field was broken up and planted to corn and soybeans and made a good crop of both, while all other fields of corn in the vicinity, planted after rye were practically destroyed.

Smith (1915) states that badly infested fields in Missouri that were planted to corn and soybeans have given good crops of both, while adjoining fields of corn planted alone were totally destroyed. Even in the fields where both corn and beans were planted, hills of corn containing no beans were completely destroyed, while the corn with the beans was unmolested.

Replies to numerous inquiries in different sections as to differences noted in corn and soybeans as to chinch bug damage showed that in every case the chinch bugs were not nearly so bad where the soybeans were in the corn.

Two possible explanations have been advanced. It is well known that insects are repulsed by odors and it may be that the odor of soybeans is repulsive to chinch bugs. Again, the chinch bug prefers sunshine and dry weather, while the soybeans with corn produce shade, and consequently a damp condition, which might be the cause of their absence in large numbers.

Green Clover Worm.—During the season of 1919, the green clover worm (*Plathypena scabra Fabr.*) caused serious injury to soybean fields throughout southern Virginia and eastern North Carolina. The injury is caused by the worms eating the leaves and occasionally the blossoms, stripping entire fields in a short time. Beginning the latter part of July, the injury subsided by the middle of August, and many fields, especially of late maturing varieties, quickly put out new growth and recovered, but in many cases the earlier maturing varieties were ruined. Extensive studies were made by Sherman (1920), Sherman and Leiby (1920), and Smith (1919) during the course of the outbreak as to methods of control.

In the work with control measures, Sherman (1920) found in North Carolina that powdered arsenate of lead at the rate of 1 to 8 lb. of lime was effective and safe to the plant. Its use is deemed practicable in large areas of soybeans, especially when grown in rows. It is not too costly and pays a good profit on its use, if applied before the injury reaches its maximum. It is stated that a very careful farmer whose field was under observation tried arsenate alone successfully as a test, a very light application having been made. It was found that there was little danger from the use of hay treated in this way, the material gradually disappearing from the leaves.

Mexican Bean-beetle.—Hinds (1921) reports that crops of soybeans in Alabama while usually less severely injured than other beans, have in some cases been riddled about as completely as table beans by the Mexican bean-beetle.

Bourletiella hortensis—Corbett (1913) reports that this insect attacks the undersurface of the cotyledons of soybeans near the edge, where it eats out crescent-shaped holes. It also eats small holes in the upper surface of the seed leaves. Some plants are said to be damaged to such an extent that they die. The damage of principal importance is done while the plants are in the seed leaf stage.

Other Insects.—Caterpillars sometimes eat the foliage but the damage from such insects is seldom injurious. The black blister-

beetle has been reported in a few cases to have done considerable damage to soybean fields but in general this insect can not be considered a serious pest.

Rodents.—Rabbits are most troublesome, as they are very fond of the soybean plant and have been known to destroy considerable areas. Where rabbits are abundant, soybean culture in small areas is practically impossible unless the field can be inclosed with rabbit-proof fencing. In some of the northern states, woodchucks have caused considerable damage to small plantings of the soybean.

BIBLIOGRAPHY

Adams, G. E., 1903. Soybeans: Culture. R. I. Agric. Exp. Sta., Bull. 92, 119–127.

Aiton, William, 1812. Hortus Kewensis.

Aitchison, J. E. T., 1881. Leguminosæ. The Kuram Valley. Afghanistan. Journal of the Linnaean Society, **8**: 50.

Albertoni, E. Novi, 1893. Sul bilancio nutritivo del contadino italiano. R. Accademe delle scienze de Bologna.

Alvord, H. E., 1890. Silage for heifers. Md. Agric. Exp. Sta., Bull. 8.

Ames, J. W. and Boltz, G. E., 1916. Sulfur in relation to crops and soils. Ohio Agric. Exp. Sta., Bull. 292.

Annett, H. E., 1914. The urease content of certain Indian seeds. Biochem. Jour., **8**: 449–452.

Atwater, W. O. and Phelps, C. S., 1898*a*. Composition of soybeans as affected by nitrogenous fertilizers. Conn. Agric. Exp. Sta. (Storrs) Rpt., **1898**: 149–154; 200–203.

1898*b*. Nitrogenous fertilizers for. Conn. Agric. Exp. Sta. (Storrs) Rpt., **1898**: 148.

1900. Nitrogenous fertilizers for. Conn. Agric. Exp. Sta. (Storrs) Rpt., **1900**: 34–40; 52–55; 59–60.

Bailey, H. S. and Reuter, B. E., 1919. The production and conservation of fats and oils in the United States. U. S. Dept. of Agric., Bull. 769.

Baker, J. G., 1879. Hooker, Fl. Brit. Ind., **2**: 184.

Balfour, Edw., 1885. Glycine hispida, Bentham. The Cyclopedia of India and of Eastern and Southern Asia, **1**: 303, 1213: **1**: 697, 715.

Ball, C. R., 1907. Soybean varieties. U. S. Dept. Agric. B.P.I., Bull. 98.

Balland, A., 1917. La soya dans l'alimentation francaise. Compt. Rend. Acad. Sci. Paris, **164**: 300–302.

Bartlett, J. M., 1904. Digestion experiments with sheep and steers. Maine Agric. Exp. Sta., Bull. 110.

Barton, A. W., 1920. The lipolytic activity of the castor and soybean. Jour. Amer. Chem. Soc., 42 (1920), No. **3**: 620–631.

Basu, B. C., 1902. The cultivation of pulse crops in the Assam Valley. Bull. 9, Agric. series 5, Agric. Dept., Assam: **15**.

Belohubek, Ant., 1890. Le schoyou. Chemische Centralblat; 1–132.

Beltzer, F. G. J., 1911. Vegetable milk, casein and cheese. Sci. Amer. Sup. 72, **1879**: 115.

Benedict, F. G., 1899. Analyses of fodders and feeding stuffs. Conn. Agric. Exp. Sta. (Storrs) Rpt., **1899**: 212–217.

Bennett, R. L., 1898. Some experiments on the fattening value of certain foods gathered by hogs. Ark. Agric. Exp. Sta., Bull. 54.

Bentham, George, 1865. Jour. Linnaean Soc., **8**: 266.

Bergh, O. I., 1920. Sunflowers and soybeans for silage. Minn. Agric. Exp. Sta., 28th Ann. Rpt., 1919–20. With Central Exper. Sta., Grand Rapids, **78**.

Bergius, P. J., 1764. Soja Bonan. K. Svenska Vetensk. Akad. Handl., **25**: 271–275, pl. IX.

Bernard, P., 1916. Le Tourteau de soja. Progres Agricole, **30**: 601–602.

Billings, G. A., 1905. Test of varieties. N. J. Agric. Exp. Sta., Rpt., **1905**: 370–371.

Blair, A. W., 1917. Maintaining the nitrogen supply of the soil. N. J. Agric. Exp. Sta., Bull. 305.

Blasdale, W. C., 1899. Some Chinese vegetable food materials. U. S. Dept. of Agric. O.E.S., Bull., **68**: 32–36.

Bloch, A., 1906. Einige worte uber die Fabrikation und zusammensetzung des Teou Fou Chinesischer Bohnenkase, aus der soja hispida bereitet. Bull. Sci. Pharmacol., **13**: 138–143.

1907. Le Soya. Bull. des. sciences pharmacologiques, Sept. and Oct.

Blondel, M. R., 1888. La structure des graines de soja hispida. Jour. de pharm. et de chem., **18**: 587.

Bontoux, E., 1911. The soybean and its products. Matieres Grasses. 14. No. **36**: 2195–2199.

Booerhaave, Herman, 1720. Index Alter Plantarum quae in Horto Academico Lugduno-Batavo Aluntur, pts. **2**: 28.

Borghesani, Guido, 1907. Sui pentosani della Soia hispida. Le stazioni sperismentali agrar italiane v. 60, fasc., **2**: 118–120.

Bowers, W. G., 1919. Some studies on the nutritive value of the soybean in the human diet. N. D. Agric. Exp. Sta., Special Bull., Food Dept., **5**: 13.

Brawngart, R., 1879. Die Cultur der Sojabohne in Weihenstephan in Jahre, 1878. Zeits. des Landw. Ver. in Bayern: 60–64.

Briggs, L. J. and Shantz, H. L., 1914. Relative water requirements of plants. Jour. Agric. Res., **3**.

Brenier, H., 1910. La question du soja. Bull. Econ. de l'Indochine, **12**: 105–128.

Brewer, Lucile and Canon, Helen, 1915. Beans and similar vegetables as food. N. Y. State Coll. of Agric., Cornell Reading Courses, Food Series IV, No. **16**: 89.

Brooks, W. P., 1888. Soybeans for egg production. Vegetable vs. animal albuminoids. Mass. Agric. Exp. Sta., Bull. 122: 46.

1890. General results of a trial of a few Japanese crops. Mass. (Hatch) Agric. Exp. Sta., Bull. 7: 14–17.

1894. Soybean meal vs. gluten meal for milch cows. Mass. Agric. Exp. Sta. (Hatch) Rpt., **1894**: 12.

1895. Soja Beans. Mass. Agric. Exp. Rpt., **1895**: 200.

1900. Fertilizing value. Mass. Agric. Exp. Sta., Rpt., **1900**: 91–123.

1904. Green manuring and cover crops. Mass. Agric. Exp. Sta., Circ., 37.

1904. Relative value of cottonseed meal and soybean meal as food for milch cows. Mass. Hatch Agric. Exp. Sta., 6th Ann. Rpt., **1903**: 13–14.

Browne, D. J., 1854. Soja Beans. Rpt. of the Com. of Patents. Agric., **15**: 194.

Bruce, W., 1910. Soybean cake vs. linseed cake. Edinb. and East of Scotland Coll. Agric. Bull., **21**: 15.

1911. Soybean cake, cattle feeding. Edinb. and East of Scot. Coll. Agric. Rpt., **25**: 16.

Bruyn, B. R. de, 1916. Soyakoek en soyameel. In. en Hitvoer, No. **1**: 740.

Bryan, O. C. 1922. Effect of different reactions on the growth and nodule formation of soybeans. Soil Sci., v. 13, No. **4**: 271–302.

Bryan, O. C. and Fred, E. B., 1920. Acidity influences inoculation and growth. Wis. Agric. Exp. Sta., Bull. 323.

Burgess, J. L., 1919. Relation of varying degrees of heat to the vitality of seeds. Jour. of Amer. Soc. of Agron., v. XI, No. **3**: 118–120.

Burlison, W. L., 1916. Availability of mineral phosphates for plant nutrition. Jour. of Agric. Res., v. **6**: 485–514.

Burlison, W. L. and Allyn, O. M., 1917. Soybeans and cowpeas in Illinois. Ill. Agric. Exp. Sta., Bull. 198.

Burmann, Jan, 1737. Thesaurus Zeylanicus, 190.

Burney, W. B., 1888. Analyses. S. C. Agric. Exp. Sta., Bull. 3, 37.

Butz, G., 1906. Test of commercial cultures for legumes. Pa. Agric. Exp. Sta., Bull. 78.

Caldwell, R. E., 1913. Soybeans and alfalfa hay for milk cows. Ohio Agric. Exp. Sta., Bull. 267.

Calvino, Mario, 1920. Estudio sobre el cultivo de la soya en Cuba. Rev. Agric. Com. y Trab. (Cuba) **3**: 124–121.

Carlyle, W. L. and Iddings, E. J., 1912. Hog raising for the Idaho farmer. Idaho Agric. Exp. Sta., Bull. 74.

Carmichael, B. E., 1909. Rations for fattening swine. Ohio Agric. Exp. Sta., Bull. 209.

Carmichael, B. E. and Eastwood, G. R., 1912. Forage crops for swine. Ohio Agric. Exp. Sta., Bull. 242.

Carmichael, B, E., and Hammond, J. W., 1912. Rations for fattening range lambs. Ohio Agric. Exp. Sta., Bull. 245.

Cauthen, E. F., 1918. Soybeans in Alabama. Ala. Agric. Exp. Sta., Bull. 203.

Champion, L., 1885. Industrie ancienne and moderne de l'empire chinois.

Chevalier, J., 1909. Diabetic bread from soybeans and gluten. Bull. Gen. Ther. Med. et Chirurg., **157**: 845.

Chilcott, E. C., 1897. Soybeans. S.D. Agric. Exp. Sta., Bull. 51.

Church, A. H., 1886. Food grains of India.

Churchill, F. G., 1919. The soybean, an annual legume. Ia. Agric. Exp. Sta., Extens. Bull. 68.

Clinton, G. P., 1915. Bacterial leaf-spot of soybeans. Conn. Agric. Exp. Sta., Rpt. 1915, pt. **6**: 446–447.

Coerper, Florence M., 1919. Bacterial blight of soybean. Jour. Agric. Res., v. 18, No. **4**: 179–194.

Collins, S. H., 1912. Soybean cake for cattle and sheep. County Northumb. Ed. Corn., Bull. 17.

Collison, R. C., 1912. Inorganic phosphorus in plant substances. Jour. Biol. Chem., v. 12, No. **1**: 65–72.

Connell, J. H. and Clayton, J., 1896. Variety test. Texas Agric. Exp. Sta., Bull. **40**: 851, 854, 873, 874.

Cook, A. S., 1913. Soybean meal vs. cottonseed meal for dairy cows. N. J. Exp. Sta. Rpt., **1913**: 293–316.

Cook, F. C., 1916. Boron, its absorption and distribution in plants and its effect on growth. Jour. Agric. Res., v. **5**: 877–890.

Cook, I. S. and Kemp, W. B., 1915. Soybeans, an important West Virginia crop. W. Va. Agric. Exp. Sta., Circ. 20.

Cooke, W. W. and Watrous, F. L., 1894. Variety test. Colo. Agric. Exp. Sta., Bull. 29: 7–9.

Corbett, G. H., 1913. Economic importance of the family Sminthuridæ, with notes on the attack of Bourletiella hortensis on soybeans. Agric. Students' Gaz. n. ser. v. 16 No. **4**: 128–130.

Cottrell, H., Otis, D. H. and Haney, J. G., 1900*a*. A new drought-resisting crop-soybeans. Kans. Agric. Exp. Sta., Bull. 92.

1900*b*. Inoculation experiments. Kans. Agric. Exp. Sta., Bull. 96.

Cromwell, R. O., 1917. Fusarium blight, or wilt disease of the soybean. Jour. of Agric. Res. v. 8, No. **11**: 421–440.

1919. Fusarium blight of the soybean and the relation of various factors to infection. Neb. Agric. Exp. Sta., Res. Bull. 14 (1919): 5–43.

Crow, J. W., 1911. Soybean meal for dairy cows. Ont. (Canada) Agric. Coll. and Exp. Farm Ann. Rpt. 1911, No. **37**: 145.

Crowther, C., 1916. Composition, nutritive and manurial value of various farm foods. Univ. Leeds and Yorkshire Council Agric. Ed. Pamphlet. 73 (1916) 3 ed.

Dalbey, D. S., 1903. The soybean and cowpea in Illinois. Ill. Agric. Exp. Sta., Circ. 69.

Dale, Samuel, 1705. Pharmacologiæ: 184.

1751. Pharmacologiæ, ed. **5**: 238.

Daniels, A. L. and Nichols, N. B., 1917. The nutritive value of the soybean. Jour. Biol. Chem. v. **1**: 91.

Davy, J. B., 1910. The soybean (Glycine hispida). Transvaal Agric. Jour., v. **8**: 620–626.

De Candolle, A. L. P. P., 1825. Prodomus systematis naturalis regin vegetabilis, v. **2**: 296.

1884. Origione des plantes cultivees.

De Graaff, W. C. and Van der Zande, J. E., 1916. The urease of soybeans. Chem. Weekbl., 13, (1916) No. **10**: 258–264.

De Jong, A. W. K., 1912. Fertilizer experiments with field crops. (Dept. Landb. nijv. en Handel, Dutch E. Indies), Meded Agric. Chem. Lab., No. **1**: 40.

De Lanessan, F., 1886. Les Plantes Utiles des Colonies Francais. Paris Cochinchine.

Delwiche, E. J., 1907. Report on the northern substations for 1906. Wis. Agric. Exp. Sta., Bull. 147.

Deschamp, V., 1911. The soybean. Trop. Agric. and Mag. of the Ceylon Agric. Soc., v. **37**: 410–415.

Dietrich, W., 1911. Rations for pigs. Ill. Agric. Exp. Sta., Circ. 153.

Dobbs, A. C., 1911. Soybeans in India. Rpt. Agric. Res. Inst. and Col. Pusa (India).

Dodson, W. R. and Stubbs, W. C., 1898. Variety test. La. Agric. Exp. Sta., Bull. 53, 2nd ser.

Dox, Arthur W., 1920. Notes on soybeans urease. Amer. Jour. Pharm., **92**: 153–157.

Dubard, Marcel, 1911. A Propos de Quelques Varieties de Soja. L' Agriculture Pratique des Pays chauds, v. 11, No. **98**: 422–425.

Duggar, J. F., 1903. Feeding experiments with milk cows. Ala. Agric. Exp. Sta., Bull. **123**: 51–72.

Dunne, J. J., 1913. Winter fodder of milk cows in Denmark. Hoard's Dairyman, 45 (1913) No. **25**: 832, 839.

Dutt, H. L., 1915. The soybean stem-borer. Agric. Jour. Bihar. and Orissa (India) 3(1915) No. **1**: 52–56.

Eastman, M. G., 1922. Soybean inoculation. N. H. Agric. Exp. Sta. Rpt., 1921 (Bull. **203**): 18.

Eckles, C. H., 1919. Legumes, Sudan grass and cereal crops for silage. Mo. Agric. Exp. Sta., Bull. 162.

Edie, E. S., 1909. Cultivation and uses of soybeans. Liverpool Univ. Inst. of Commercial Res. in the Tropics, Bull. v. **1**, no. **1**.

Ekeberg, K. G., 1764. On Chinesika soyan. K. Svenska Vetensh. Akad. Handl., **25**: 38–40.

Emery, F. E., 1897. Feeding experiments with milch cows. N. C. Agric. Exp. Sta., Bull. 143: 161–169.

Erf, O. and Kinzer, R. J., 1905. Swine feeding test with sorghum-seed meal, kafir corn meal, soybean meal and corn meal. Kans. Agric. Exp. Sta., Bull. 141.

Ernst, A. H., 1853. Japan Pea. Rpt. of the Com. of Patents, Agric., 224.

Etheridge, W. C., 1911. Soybean variety test. N. C. Agric. Exp. Sta., Rpt., **1911**: 16–21.

Etheridge, W. C. and Helm, C. A., 1922. Productive methods for soybeans in Missouri. Mo. Agric. Exp. Sta., Bull. 195.

Fain, J. R. and Vanatter, P. O., 1917. Soybeans and cowpeas. Ga. Agric. Exp. Sta., Circ., 46.

Falk, K. G., 1915. Studies on enzyme action, XIII. The lipase of soybeans. Jour. Amer. Chem., v. **37**: 649–653.

Falk, K. G. and Sugiura, K., 1914. Studies on enzyme action. Jour. Amer. Chem. Soc., 36 (1914) No. **10**: 2166–2170.

Fellers, C. R., 1918*a*. The effect of inoculation, fertilizer treatment, and certain minerals on the yield, composition and nodule formation of soybeans. Soil Sci., 6(1918) No. **2**: 81–129.

1918*b*. Report on the examination of commercial cultures of legume-infecting bacteria. Soil Sci., 6(1918) No. **1**: 53–57.

Fisher, M. L. and King, F. G., 1912. Supplementary pasture crops. Ind. Agric. Exp. Sta., Circ. 35.

Flagg, C. O. and Towar, J. D., 1892. Soybeans as a forage plant. R. I. Agric. Exp. Sta., Rpt. **1892**: 149–152.

Flint, P. N., 1909. Spanish peanuts, soybeans and skim milk as feeds supplementary to corn. Ga. Agric. Exp. Sta., Bull. 87.

Forbes, E. B., 1909. Specific effects of rations on the development of swine. Mo. Agric. Exp. Sta., Bull. 81.

1913. Feeding value for swine. Abs. in Sci., n. ser. 38 (1913), N. **984**: 678–679.

Forbes, E. B. and Beegle, F. M., 1916. The iodine content of foods. Ohio Agric. Exp. Sta., Bull. 299.

Forbes, E. B., Beegle, F. M. and Mensching, J. E., 1913. Mineral and organic analyses of foods. Ohio Agric. Exp. Sta., Bull. 255: 211–232.

Forbes, E. B., *et al.*, 1915. Specific effects of rations on the development of swine. Ohio Agric. Exp. Sta., Bull. 283.

Forbes, E. B. and Keith, M. Helen, 1914. Phosphorus Compounds in Animal Metabolism; 78.

Franchet, Audrieu Perre and Savatier, Lud., 1875. Enumeratio Plantarum in Japonia sponte crescentum huiusque rite cognitarium adjectis descriptionibus specierum pro regione novarum quibus accedit determinatio herbarum in libris paponicus Lo Mokio Zoussetz Xylographice delineatarum auctoribus. A. Franchet et Lud. Savatier., v. **1**: 108.

Frear, D. W., 1922. Separating cracked from whole soybeans. Mo. Agric. Sta., Leaflet, 18.

Frear, W., 1905. Composition of soybeans. Pa. Agric. Exp. Sta., Rpt. **1905**: 39–40.

Fred, E. B., 1908. Inoculation experiments. Va. Agric. Exp. Sta., Rpt. **1908**: 130–131.

1916. Relation of green manures to the failure of certain seedlings. Jour. Agric. Res., v. **5**: 1161–1176.

Fred, E. B. and Davenport, 1922. Bacteria for legumes. Wis. Agric. Exp. Sta., Extens. Cir. 143.

Fred, E. B. and Graul, E. J., 1916. Gain in nitrogen from the growth of legumes on acid soils. Wis. Agric. Exp. Sta., Res. Bull. 39.

1919. Effect of inoculation and lime on the yield and on the amount of nitrogen in soybeans on acid soil. Soil Sci. 7 (1919), No. **6**: 455–467.

Fremery, F. de, 1912. Soja en Katoen als Voorvrucht. Meded. Deli-Proefstat. Medan. Jahrg. **7**: 57–58.

Friedenwald, J. and Ruräh, J., 1910. The soybean as a food in diabetes. Jour. Amer. Med. Sci. v. 54, No. **21**: 1720.

Fromme, F. D., 1921. Diseases of cereal and forage crops in the United States in 1920. U. S. Dept. of Agric. B.P.I., Plant Disease Bull. Sup. **15**: 173..

Fruwirth, C., 1898. Anbau der Hülsenfruchte. Die Sojabohne: 214.

1915*a*. Die sojabohne. Illus. landw. Ztg. v. **35**: 13–14.

1915*b*. Die sojabohne. Sonderabdruck aus Fühling's landwirtschaftlichen Zeitung, 64.

Gardner, H. A., 1914. Repainting tests on paint oils. Edu. Bur. Sci. Sect. Paint Mfrs. Asso. of the U. S. Circ., 30.

Gardner, M. W. and Kendrick, J. B., 1921. Soybean mosaic. Jour. Agric. Res. v. 22, No. **2**: 111–113.

Garman, H. and Didlake, M., 1914. Six different species of nodule bacteria. Ky. Agric. Exp. Sta., Bull. 184.

Garner, W. W., Allard, H. A. and Foubert, C. L., 1914. Oil content of seeds as affected by the nutrition of the plant. Jour. Agric. Res., v. 3, No. **3**: 227–249.

Gayle, H. K. and Lloyd, E. R., 1917. Silage for fattening steers. Miss. Agric. Exp. Sta., Bull. 182.

Geismar, L. M. and Smith, C. D., 1903. Culture. Mich. Agric. Exp. Sta., Spec. Bull. 20.

Georgeson, C. C. and Cottrel, H. M., 1890*a*. Forage plants for Kansas. Kans. Agric. Exp. Sta., Bull. 18: 175–188.

1890*b*. Some Japanese Beans. Kans. Agric. Exp. Sta., Bull. 19: 199–201.

Georgeson, C. C., Burtis, F. C. and Otis, J. H., 1896. Kafir corn and soybean meal for pigs. Kans. Agric. Exp. Sta., Bull. 61.

Georgeson, C. C., Burtis, F. C. and Shelton, W., 1891. Beans, Japanese. Test of varieties. Kans. Agric. Exp. Sta., Bull. 32: 233–238.

Gibbs, H. D. and Agacoili, F., 1912. Soybean curd. Philippine Jour. Sci., Sect. A., v. 7, No. **1**: 47–54.

Gilchrist, D. A., 1909. Soybeans and soybean cakes. Mark Lane Express, 100 (1909) No. **4054**: 667.

1912. Soybean cake, feeding experiments. County Northumb. Ed. Corn., Bull. 17.

1917. Palm-kernel cake, palm-kernel meal and coconut cake compared with soy cake for fattening cattle, young store cattle, and fattening sheep. County Northumb. Ed. Corn., Bull. 25.

Gill, N., 1913–14. Soybean varieties, analyses. Ann. Rpt. Kamaun Gov't. Gardens: 2–4.

Goessmann, C. A., 1888. Fertilizer tests. Mass. Agric. Exp. Sta., Rpt. **1888**: 107–114.

1889*a*. Analyses. Mass. Agric. Exp. Sta., Rpt. **1889**: 162–166, 180–181.

1889*b*. Fertilizer tests. Mass. Agric. Exp. Sta., Rpt. **1889**: 156–167.

1890*a*. Analyses. Mass. Agric. Exp. Sta., Bull. 36.

1890*b*. Culture. Mass. Agric. Exp. Sta., Rpt. **1890**: 159–186.

1891*a*. Soiling milk cows. Mass. Agric. Exp. Sta., Rpt. **1891**: 59–73.

1891*b*. Variety test. Mass. Agric. Exp. Sta., Rpt. **1891**: 170–177.

1892*a*. Fertilizer tests. Mass. Agric. Exp. Sta., Rpt. **1892**: 178–181, 190–195.

1893*a*: Fertilizer tests. Mass. Agric. Exp. Sta., Rpt. **1893**: 220–226, 236.

1893*b*. Analyses. Mass. Agric. Exp. Sta., Rpt. **1893**: 210, 216–218.

1894*a*. Variety test. Mass. Agric. Exp. Sta., Rpt. **1894**: 231–256–262.

1894*b*. Analyses. Mass. Agric. Exp. Sta., Rpt. **1894**: 198, 232–249, 263.

1894*c*. Fertilizer test. Mass. Agric. Exp. Sta. (Hatch), Rpt. **1894**: 171–177.

Good, E. S., 1913. The growing and fattening of hogs in the dry lot and on forage crops. Ky. Agric. Exp. Sta., Bull. 175.
1918. Feeding experiments with steers and swine. Ky. Agric. Exp. Sta., Rpt. **1918**: 30–33.

Good, E. S. and Smith, M. J., 1916. Hogging down soybeans and cowpeas. Ky. Agric. Exp. Sta., Bull. 201.

Golding, J., 1909–10. Analyses of soybean cake. Midland Agric. and Dairy Coll., Bull. 10: 93–103.

Goodwin, P. W., 1911. The soybean: Varieties and culture. Trop. Agric. and Mag. of the Ceylon Agric. Soc., v. **36** No. **6**: 504.

Granato, L., 1913. La soya. Bol. Agric. (Sao Paulo) 14 ser. No. **3**: 159–167.

Grandeau, L. N., 1903. Le soja hispida. Jour. d'agriculture pratique. Nos. 26, 27 and 28.

Grantham, A. E., 1912. Soybeans. Del. Agric. Exp., Bull. 96.

Gray, D. T., 1915. Soybean pastures for hogs. N. C. Agric. Exp. Sta., Circ. 24.

Gray, D. T., 1916. Feeding experiments with pigs. N. C. Agric. Exp. Sta., Rpt. (**1915-16**): 23–31.
1917. Swine experiments. N. C. Agric. Sta., Rpt. **1917**: 33–43.
1919*a*. Swine experiments. N. C. Agric. Exp. Sta., Rpt. **1919**: 43–47.

Gray, D. T., 1919*b*. Soybean pastures for hogs. N. C. Agric. Exp. Sta. Extens., Circ. 85.

Gray D. T., Duggar, J. F. and Ridgway, J. W., 1908. Feeds supplementary to corn for southern pork production. Ala. Agric. Exp. Sta., Bull. 143.

Gray, D. T., Ridgway, J. W. and Eudaly, E. R., 1911. Corn, soybean pasture, tankage, cottonseed meal for fattening hogs. Ala. Agric. Exp. Sta., Bull. 154.

Gray, D. T. and Shook, L. W., 1912. Feeding experiments. Ala. Agric. Exp. Sta., Bull. 167.

Grimme, C., 1914. Der Sojabohne und ihre Verarbeitung zu Nahrungs und Genussmitteln. Konserv. Ztg. Bd. **15**: 1–3; 10–11.

Groff, E. H., 1919. Preparation of soya sauce in Kwantung, China. Philippine Jour. of Sci., v. 15, No. **3**: 307–316.

Haas, A. R. C. and Fred, E. B., 1919. The effect of soybean germination upon the growth of its nodule-forming bacteria. Soil Sci., 7 (1919), No. **3**: 237–244.

Haberlandt, F., 1877. Der anbau der rauhhaarigen sojabohne. Landw. Vers. Stat. Bd. **20**: 247–272.
1878. Die sojabohne.

Hacklemann, J. C., 1915. Field tests. Mo. Agric. Exp. Sta., Bull. 131.
1922. Growing soybeans in Illinois. Ill. Agric. Exp. Sta., Circ. 255.

Hahn, P. D., 1915. Contribution to the chemistry of the soyabean. The South African Jour. of Sci., **12**: 124–126.

Halsted, B. D. *et al.*, 1911. Hypocotyl studies. N. J. Agric. Exp. Sta., Rpt. **1911**: 360–382.

1913. Some correlation studies of hypocotyls. N. J. Agric. Sta., Rpt. **1913**: 588–611.

1914*a*. A study of influence of pod position upon viability and vigor of seedlings. N. J. Agric. Exp. Sta., Rpt. **1914**: 321–329.

1914*b*. Abortiveness of ovules in connection with position in pods. N. J. Agric. Exp. Sta., Rpt. **1914**: 321–329.

Hanausek, T. F., 1882. Die Sojabohne. Irmisha II.

1884. Ueber das Vorkommen von Starkemehl in der sojabohne. Stschr. Allg. Oesterr. Apoth. ver. **22**: 474.

Hansen, J., 1909. Soybean cake. Deut. Landw. Presse, 36 (1909). No. **41**: 439, 440, 452, 453.

Hansson, N., 1909*a*. Soy meal and soy cakes. K. Landtbr. Akad. Och. Tidskr. 48 (1909). no. **3**: 272–274.

1909*b*. Soybean cake and soybean meal for feeding milk cows. Meddl. Centralanst. Forsok. Jordbruksomradet, No. **15**: 51. Fühling's Landw. Ztg. 59, no. **2**: 49–63.

Hanzawa, J., 1912. Soy sauce, Fungi and composition of Japanese Tamari-kojii. Myco.-Centbl. 1 (1912), No. **6**: 163–166.

Harcourt, R., 1911. Cattle feeds. Ann. Rpt. Ontario Coll. and Exp. Farms. v. **37**: 69–71.

Hartwell, B. L., 1911. Nitrogen fixation. 32nd. Ann. Meeting. Soc. Prom. Agric. Sci.

1920. Field experiments which included the soybean. R. I. Agric. Exp. Sta., Bull. 183.

Hartwell, B. L. and Pember, F. R., 1911. Nitrogen accumulation. R. I. Agric. Exp. Sta., Bull. 147.

Harz, C. O., 1880*a*. Ueber soja hispida Mönch. die rauhhaarige sojabohne characteristik der Culturracen. Zeit. des. Land. Ver. in Bayern. 210, 1880.

1880*b*. Ueber Soya hispida. Moen. die rauhhaarigen sojabohne; Kulturversuche. Zeit. des Land. ver. in Bayern. 247.

1885*a*. Ueber den Starkegehalt der Sojabohne. Ztschr., Allg., Oesterr. Apoth. ver. 23–40.

1885*b*. Landwirtshaftliche Samenkunde. 692. Berlin.

Haselhoff, E., 1910–1911. Analyses: Soybean meal. Jahresbu. Landw. Vers Stat. Horleshausen, 7–11.

1912. Swine fattening experiments with soybean meal. Fühling's Landw. Ztg. 6, No. **12**: 401–414.

Hawk, W., 1911. Soybean cake, feeding value. Cornwall County Council Agric. Expts.: 25–29.

Hayes, H. K., *et al.*, 1915. Test of varieties. Conn. Agric. Exp. Sta., Bull. 185.

Hays, F. A., 1919*a*. Soybean forage for fattening growing pigs. Del. Agric. Exp. Sta., Bull. 124: 38.

Hays, F. A., 1919*b*. Efficiency of protein concentrates from different sources for growing fattening pigs. Del. Agric. Exp. Sta., Bull. 125.

Hayward, A. I., 1888. Field test and feeding value. Md. Agric. Exp. Sta., Rpt. **1888**: 71–73.

1890. Yields of forage tests. Md. Agric. Exp. Sta., Rpt. **1890**: 95–98.

HEALD, F. D., 1906. Bacterial blight. Abs. in Science. v. ser. 23 (1906). No. **590**: 564.

HEFTER, G., 1910. Technologie der Fette und Ölle. 1906–1910.

HELM, C. A., 1920. Comparison of soybeans and cowpeas for hay and seed production. Mo. Agric. Exp. Sta., Bull. 179.

HEMMI, TAKEWO, 1915. A new brown-spot disease of Glycine hispida, Maxim. caused by Septoria glycines n. sp. Trans. Sapporo Nat. Hist. Soc., v. 6, pt. **1**: 12–16.

HENRICK, J., 1910. The soybean. Trans. Highland and Agric. Soc. Scotland, ser. 5, v. **22**: 258–263.

HERMANN, PAUL, 1726. Musaeum Zeylanicum, 22.

HERMAN, V. R., 1919. Soybeans and cowpeas for North Carolina. N. C. Agric. Exp. Sta., Bull. 241.

HERNANDEZ, FRANCISCO, 1651. Nova plantarum, animalium et mineralium mexicanorum historia a Francisco Hernandez primum compiliata, dein a Nordo, Antonio Reccho in volsen digesta, a Io. Terentio. Io Fabio, et Io Fabio Columna Lynceis notis, et additionibus longe doctissimus Illustra: 887.

HILDEBRANDT, F. M., 1917. Leaf product as an index of growth in soybean. Johns Hopkins Univ. Circ., n. ser., No. 3 (**1917**): 202–205.

1921. A physiological study of the climatic conditions of Maryland, as measured by plant growth. Physio. Res. v. 2, No. **8**: 341–405.

HILLS, J. L., 1893. Soybeans and vetch for ensiling. Vt. Agric. Exp. Sta., Rpt. (**1893**): 109–110.

1895. Analyses. Vt. Agric. Exp. Sta., Rpt. 1895: 195–196.

1917. Concerning alfalfa and soybeans. Vt. Agric. Exp. Sta., Bull. **204**: 63.

1897. Corn silage vs. mixed silage. Vt. Agric. Exp. Sta., Rpt. **1896-97**: 169–173.

1899. Variety test and analyses. Vt. Agric. Exp. Sta., Rpt. **1899**: 308.

HILTNER, L., 1900. Ueber die Bakterioden der Leguminosen knollchen und ihre willkurliche erzeugung ausserhalb, des Wirtspflanzen. Centralbl. F. Bakt. 2 abt. v. **6**: 273.

1915. Darf man, namentlich in heurigen Jahre den anbau der soyabohne empfehlen? Prat. Blat. für Pflanzenban und Pflanzenschutz. v. **13**: No. **32**: 44–49.

HINDS, W. E., 1921. The Mexican bean beetle, a new pest in Alabama. Ala. Agric. Exp. Sta., Bull. 216: 11–18.

HOFMAN-BANG, N. O., 1911. Soybean cake, feeding experiments with milch cows. Ber. K. Vet. og Landbohöjskoles Lab. Landökonom, Forsog. (Copenhagen), 74 **1911**: 78.

HOLLAND, E. B., 1908. Soybeans and soybean oil. Mass Agric. Exp. Sta., Rpt. (**1908**): 111–119.

HOLLAND, J. H., 1910–11. Soybean, Glycine soja Sieb. et Zucc. G. hispida Maxim. Proceed. Linn. Soc. London, 122 sess. **1909-10**: 53–55.

HOLMES, A. D., 1918*a*. Digestibility of some oil seeds. U. S. Dept. of Agric., Bull. 687.

1918*b*. Digestibility of protein supplied by soybean and peanut press-cake flours. U. S. Dept. of Agric., Bull. 717.

1920. Digestibility of steam-cooked soybeans and peanuts. Jour. Amer. Med. Assoc., 74, No. **12**: 798–801.

Honcamp, Fr., 1910*a*. Die sojabohne und ihre Abfallprodukte. Landw. vers. stat. bd. **73**: 241–284.

1910*b*. Soybean cake, value as a feeding stuff. Deut. Landw. Presse. 37, No. **70**: 757.

1910*c*. Die Sojabohne und ihre Vertwertung. Der Tropenpflanzer, No. **12**: 613–634.

1912. Die Sojabohne. Bot. Centrbl. **33**: 333.

Hooper, David, 1911. The soybean in India. Agric. Ledger, No. 3 (Veg. Prod. Ser. No. **14**): 17–53.

1912. The soybean in India. Glycine hispida. Trop. Agric. and Mag. of the Ceylon Agric. Soc. v. **38**: 11–15, 99, 103.

Hopkins, C. G. and Sachs, W. H., 1915. Radium as a fertilizer. Ill. Agric. Exp. Sta., Bull. 177.

Hosie, A., 1904. Manchuria: 181.

Hughes, H. D. and Wilkins, F. S., 1920. Soybeans in Iowa. Iowa Agric. Exp. Sta., Circ. 65.

Humphrey, G. C. and Fuller, J. G., (1904, 1905, 1906). Soybeans vs. wheat middlings as a supplement to corn meal for growing and fattening pigs. Wis. Agric. Exp. Sta., Rpt. (**1903–04**): 32–40; Rpt. (1904–5), 21–30; Rpt. (**1905–6**): 33–46.

Humphrey, G. C. and Kleinheinz, F., 1905. The value of soybeans in grain rations for lambs. Wis. Agric. Exp. Sta., Rpt. **1904–5**: 65–68.

Huston, H. A. and Bryan, A. H., 1900. Analyses. Ind. Agric. Exp. Sta., Rpt. **1900**: 81–82.

Hutchison, C. B. and Douglas, T. R., 1915. Soybean culture in southwest Missouri. Mo. Agric. Exp. Sta., Bull. 123.

Hutchinson, H. P., 1910. The soybean as an English crop. Jour. of the S. E. Agric. Wye, Kent, No. **19**: 318–321.

Iinuma, Yokusai, 1912. Smoku-Dzusetsu, or an inconography of plants indigenous to, cultivated in, or introduced into Nippon. Japan, pt. 1, Herbaceous Plants: 945–951.

Iowen, I. L., *et al.*, 1914. Cost of production. N. J. Agric. Exp. Sta., Rpt. (**1914**): 201–206.

Irish, H. C., 1901. Classification of varieties. Twelfth Annual Rpt. Mo. Bot. Garden: 147.

Itano, A., 1918. Soybeans as human food. Mass. Agric. Exp. Sta., Bull. 182.

Itie, G., 1910–11. Le soja, sa culture, son avenir. L'agriculture pratique des pays chauds. v. 10, No. **82**: 37–49; v. 10, No. **83**: 137–144; v. 10, No. **84**: 231–246; v. 10, No. 93: 485–493; v. 11, No. **94**: 55–61.

Jenkins, E. H., 1913. Soybean culture. Conn. Agric. Exp. Sta., Bull. 179.

1915*a*. Field test of soybeans, 1914. Conn. Agric. Exp. Sta., Bull. 185.

et al., 1915*b*. Test of soybeans. Conn. Agric. Exp. Sta., Bull. 191.

Jenkins, E. H., Street, J. P. and Hubbell, C. D., 1916. Tests of soybeans, 1915. Conn. Agric. Exp. Sta., Bull. 191.

1917. Test of soybeans, 1916. Conn. Agric. Exp. Sta., Bull. 193.

JOHNS, C. O. and FINKS, A. J., 1921. The nutritive value of soybean flour as a supplement to wheat flour. Amer. Jour. of Physio. v. 55, No. **3**: 455–461.

JOHNSON, A. G. and COERPER, FLORENCE, M., 1917. Abs. in Phytopath. 7 (1917), No. **1**: 65.

JOHNSON, O. T. and FOARD, W. E., 1915. Cost of production. Mo. Agric. Exp. Sta., Bull. 125.

JONES, D. F. and HAYES, H. K., 1916. The purification of soybean varieties. Conn. Agric. Exp. Sta., Rpt. 1916, pt. **5**: 348–353.

JUNELLE, H., 1914. Les cultures coloniales, Glycine hispida, ed. 2, v. 5. Plantes Olegineŭses: 108–112.

JUNGHUHN, FR., 1853. Plantæ Junghuhnianæ. Enumeratis Plantarum, quas in Insulis Java et Sumatra: 253.

KAEMPFER, ENGELBERT, 1712. Amoenitatum Exoticarum Politico-Physico-Medicarum: 837.

KAFEMANN, R., 1913. Human food. Aguman- a new nutritive meal made from the soybean. Umschaw, 17 (1913), No. **50**: 1041–1043.

KATAYAMA, T., 1908*a*. Vegetable sheese. Bull. of the Coll. of Agric. Tokyo, v. **7**: 117–119.

1908*b*. Condensed vegetable milk. Bull. of the Coll. of Agric. Tokyo, v. **7**: 113–115.

KATSUFUJI, KOICHI, 1919. "Yellow Dwarf," a new nematode disease of soybean. Ann. Phytopath. Soc. Japan 1, **2**: 12–16.

KAUPP, B. F., 1917. Soybean meal for little chicks. N. C. Agric. Exp. Sta., Rpt. **1917**: 57.

1919. The value of soybean meal as a feed for chicks. Poultry Item, 1, **1919**: 6–7.

KEIMATSU, S., 1911. Soybean oil. Chem. Ztg. v. 35, No. **91**: 839–840.

KELLEY, W. P., 1915. Biochemical decomposition. Hawaii Agric. Exp. Sta., Bull. 39.

KELLNER, O. J., 1893*a* Tofu cakes. Bull. of the Coll. of Agr. Tokyo, v. 1, no. **4**: 24.

1893*b*. Feeding experiments with sheep. Bull. of the Coll. of Agri. Tokyo, v. 1, no. **2**: 39–42.

1893*c*. Miso. Bull. of the Coll. of Agric., Tokyo, v. 1, no. **6**: 1–3.

1895. Sur la preparation du sake du soyon et du miso. Chem. Ztg., v. **19**: 120–165.

KELLNER, O. J., 1910. Futterungsversuche mit schweinen uber die verdaulichkeit getrochneter kartoffeln und des entfetteln sojabohnenmehle. Landw. vers. stat. bd. **73**: 235–240.

KENDRICK, J. B. and GARDNER, M. W., 1921. Seed transmission of soybean bacterial blight. Phytopath. **11**: 340–342

KENNARD, D. C., and WHITE, P. S., 1922. Mineral mixtures for growth of chickens and egg production. Mo. Bull., Nov., Dec., Ohio Agr. Exp. Sta., Vol. 7, No. 11.

KENNARD, D. C., HOLDER, R. C., and WHITE, P. S., 1922*a*. The utilization of soybean and corn proteins as affected by suitable mineral supplements. Amer. Jour. of Physiol., Vol. 59, No. 1:298.

KENNARD, D. C., HOLDER, R. C., and WHITE, P. S., 1922*b*. Mineral

supplements to rations for chickens; corn meal and soybean meal. Poultry Science, Vol. 1, Feb., March.

Kennaway, E. L., 1920. Jour. Exp. Path. 1 (1920) no. **3**: 135–141.

Kerr, A. P., Garrett, J. B. and Quereau, F. C., 1916. Use of soybeans as green manure. La. Agric. Exp. Sta., Rpt. **1915**: 8–11, 15–17, 27–32.

Kiesselbach, T. A., 1915. Soybeans and cowpeas. Nebr. Agric. Exp. Sta. Bull. 150.

1918. Soybeans. Nebr. Agric. Exp. Sta., Bull. 166.

Kilgore, B. W. *et al.*, 1902. As green manure, N. C. Dept. of Agric. Bull. v. 23, **1**: 25.

King, F. C., 1909. Pasture for hogs. Mo. Bd. Agric. Bull. 7 (1909), No. 5.

1920. Ground soybeans for fattening cattle. Ind. Agric. Exp. Sta., Bull. 237.

Kirchner, O., 1895. Die Wurzelknollchen der Sojabohne. Conn's Beitrage zur Biologie der Pflanzen xvii, **2**: 213–223.

Klimmer, M. and Kruger, H., 1914. Classification of nodule bacteria. Central. Bakt., etc., 2 abt. 40 (1914). No. **11–13**: 256–265.

Klimont, J., 1911. The refraction constants of vegetable oils. Ztschr. Angew. Chem. 24, no. **6**: 254–256.

Kondo, N., 1913. Soybeans. Anatomical studies. Ztsch. Untersuch. Nahr. W. Genussmtl. bd. 25 No. **1**: 1–56.

Korentschewski, W. and Zimmerman, A., 1905. Soybean oil, digestibility. Vyestnik Obshch. Hig. Sudeb. i Prakt. Med., **5**: 690–693.

Krauss, F. G., 1908. Field crops at Hawaii Station. Hawaii Agric. Exp. Sta., Rpt. **1908** : 82–84.

1911. Leguminous plants, Culture in Hawaii. Hawaii Agric. Exp. Sta., Bull. 23.

Labbé, H., 1911. Le soja et ses usages. Revue Scient. annee 49, semestre **1**: 171–176.

Lane, C. B., 1899. Soil inoculation experiments with soybeans. N. J. Agric. Exper. Sta., Rpt. **1899** : 199–200.

1903. Feeding experiments with milch cows. N. J. Agric. Exp. Sta., Rpt. **1903**: 388–411.

1904. Feeding experiments with milch cows. N. J. Agric. Exp. Sta., Bull. 174.

Langworthy, C. F., 1899. Soybeans as food for man. U. S. Dept. of Agric. Farmers' Bull. 58.

Layosa y Makalindong, P., 1918. Field tests of soybeans. Philippine Agr. and Forester, 6 (1918), no. **10**: 276–291.

Lechartier, G., 1903. Etude sur le soja hispida. Ann. sci. agron. t. **1**: 380–396.

Le Goff, J. M., 1910. Le soja dans l'alimentation des diabetiques. Extract de la gazette des hopiteaux du mars.

Leonard, L. T., 1916. Variations in nodule formation. Jour. Amer. Soc. Agron. v. **8**: 116–118.

Levallois, A., 1881. Ueber die zuckerartige substanz in den samen von soja hispida. Repertoire de Pharmacie. 9, Bd. Nr. **11**: 518.

Lewis, H. R., 1917. Efficiency of protein carriers as measured by fecundity. Jour. Amer. Assoc. of Instructors and Investigators in Poultry Husbandry, v. 3, no. 4.

LEWIS, H. R. and CLARK, A. L., 1913. Soybeans as a green feed for chickens. N. J. Agric. Exp. Sta., Rpt. (**1913**): 241–243.

LEWIS, H. R. and THOMPSON, W. C., 1915. Feeding chickens. N. J. Agric. Exp. Sta., Rpt. **1915**: 93–120.

LEWKOWITSCH, J. C., 1904. Chemical Technology and Analyses of Oils, Fats and Waxes. 3rd. ed. v. **2**: 506–508.

LINDER, U. V., 1912. Soybean cheese. Jour. Indus. and Engin. Chem., 4, no. **12**: 897–898.

LINDSEY, J. B., 1893*a*. Feeding experiments with milch cows. Mass. Agric. Exp. Sta., Rpt. **1893**: 15–45.

1893*b*. Feeding experiments with steers. Mass Agric. Exp. Sta., Rpt. **1893**: 57–76.

1894. Feeding test. Mass. Agric. Exp. Sta., Rpt. **1894**: 32–41.

1903. Dairy and feeding experiments. Mass. Agric. Exper. Sta., Rpt. **1902**: 57–68.

1905. Digesting experiments with sheep. Mass. Agric. Exper. Sta., Rpt. **1905**: 74–75.

1907. The effect of food upon the composition of milk and butter fat and upon the consistency or body of butter. Mass. Agric. Exp. Sta., Rpt. **1907**: 109–112.

1908. Soybean meal for dairy cows. Mass. Agric. Exp. Sta., Rpt. (1908).

LINDSEY, J. B., HOLLAND, E. B. and BILLINGS, G. A., 1896. The effect of narrow and wide rations on the quantity and cost of milk and butter, and on the composition of milk. Mass. Agric. Exp. Sta., Rpt. **1896**: 100.

LINDSEY, J. B., HOLLAND, E. B. and SMITH, P. H., 1906. Digestibility of soybean fodder. Mass. Agric. Exp. Sta., Rpt. **1906**: 95–156.

1908. Effect of soybean meal and soybean oil upon the composition of milk and butter fat, and upon the consistency or body of butter. Mass. Agric. Exp. Sta., Rpt. 1908, pt. **2**: 66–110.

1909. Effect of soybean meal and soybean oil upon the composition of milk and butter fat, and upon the consistency or body of butter. Mass. Agric. Exp. Sta., Rpt. **1909**: 66–110.

LINNAEUS, CAROLUS, 1737. Hortus Cliffortianus, 499.

1747. Flora zeylaniaca.

1749. Materia medica.

1753. Species Plantarum.

1763. Species Plantarum, ed. 2.

1767. Species Plantarum, ed. 3.

LI YU YING and GRANDVOINNET, L., 1911–12. Le Soja: L'Agriculture Pratique v. 11, Nos. 102, 104, **105**: 176–196, 360–375; 459-474; v. 12, nos. 106, 107, 108, **109**: 28–38, 120–132, 213–223, 302–307.

LIPMAN, J. G., 1911. Soybean meal as fertilizer. Centbl. Bakt. (etc.), 2 abt. 31, Nos. 1–4.

LIPMAN, J. G. and BLAIR, A. W., 1916. The yield and nitrogen content of soybeans as affected by inoculation. Soil Sci. v. 1, No. **6**: 579–584.

1917. Vegetation experiments on the availability of phosphorus and potassium compounds. N. J. Agric. Exp. Sta., Rpt. **1917**: 353–368.

1918. The influence of lime upon the yield of dry matter and nitrogen

from different varieties of soybeans. N. J. Agric. Exp., Rpt. **1918**: 189–193.

Loew, O., 1906. Some unusual Japanese food products. Mitl. Deut. Gesell. Naturn, Volkerk Ostasiens, 11, No. **1**: 109–111.

Long, C. M., 1914. Are soybeans offensive to chinch bugs? Wallace's Farmer, v. 39, No. **47**: 1914.

Loureiro, Juan de, 1793. Flora Cochinchinensis, v. **2**: 53.

Low, W. H., 1920. Soybean oil. Jour. Indus. and Engin. Chem. 12 (1920) No. **6**: 572–573.

Mach, F., 1910. Analyses, soybean cake. Ber. Grossh. Bad. Landw. Vers. Anst. Augusteub: 17–30.

Machintosh, J. and Goodwin, W., 1909. Soybean cake. Jour. Southeast Agric. Coll. Wye., No. **18**: 225–230.

McBryde, J. B., 1889*a*. Soja bean vines, analyses. S. C. Agric. Exp. Sta., Rpt. **1889**: 178–180.

1889*b*. Culture experiments. S. C. Agric. Exp. Sta., Rpt. **1889**: 342–344.

1890. Soja bean vines, analyses. S. C. Agric. Exp. Sta., Bull. 8.

Mairs, T. I., 1911. Some soiling crops for Pennsylvania. Pa. Agric. Exp. Sta., Bull. 109.

Mallere, A., 1912. Feeding value of soybean cake and its influence on the quality of butter. Ann. Sci. Agron., 4, ver. 1 (1912). I. No. **2**: 81–100; **3**: 226–228.

Malpeaux, L., Soybean cake for dairy cows. Vie. Agr. Rurale. No. **5**: 125–136.

Marpann, G., 1910. Untersuchungen des chineischen bohnenöls. Jour. Landw. No. **3**: 243–250.

Marshall, Jr., E. K., 1914. The effect of dilution, acids, alkailiis, and ethyl alcohol on soybean urease. Jour. Biol. Chem. v. 17. No. **3**: 351–361.

Martens, G. M., 1869. Die Gartenbohnen.

Matthes, H. von and Dahle, A., 1911. Ueber Sojabohnenöl. Arch. Pharm. Bd. 249. No. **6**: 424–444.

Maximowicz, C. J., 1873. Diagnoses plantarum novarum Japoniæ et Mandshuriæ. In Bull. Acad. Sci. St. Petersburg, v. **18**: 398.

Maxwell, W., 1890. On the presence of sugar yielding insoluble carbohydrates in seeds. Amer. chem. Jour., No. **12**: 51–60.

McHargue, J. S., 1913. The occurrence of barium in tobacco and other plants. Jour. Amer. Chem. Soc., 35 (1913) **6**: 826–834.

McLean, F. T., 1915. Relation of climate to monthly weather review. 43 (1915), No. **2**: 65–72.

1917. A preliminary study of climatic conditions in Maryland, as related to plant growth. Physiol. Res. 2 (1917), No. **4**: 129–208.

Mease, James, 1804. Willich's Domestic Encyclopedia. 1st American Ed. Philadelphia, **1804**: 13.

Megee, C. R., 1920. Soybeans. Mich. Agric. Exp. Sta., Spec. Bull. 100.

Meissl, E. and Böcker, F., 1883. Sur les constituents de la grain de soja. Monatschefte für Chemie. IV: 349–368.

Mellana, E., 1914. Hardened oils. Ann. chim. Appl. (Rome). 1. No. **9–10**: 381–387.

MENDEL, L. D. and FINE, M. S., 1911. Studies in nutrition, IV. Utilization of the proteins of the legumes. Jour. Biol. Chem. v. **10**: 433–458.

METZGER, J. E. and EPPLEY, G., 1920. Variety tests of corn, wheat, and soybeans. Md. Agric. Exp. Sta., Bull. 237.

MINNS, E. R. Soybeans as a supplementary silage crop. N. Y. Agric. Exp. Sta. (Cornell), Bull. 310.

MIQUEL, FREDERICH ANTON WILHELM, 1855. Floræ Indiæ Bataviæ: 223.

MIYAKE, K., 1912. Pentosans and methylpentosans in seeds in Glycine hispida and Phaseolus vulgaris during germination. Jour. Coll. Agri. Tohoku Imp. Univ., 4 (1912). No. **8**: 327.

MOENCH, KONRAD, 1794. Methodus plantas horti botanici et agri. Marburgensis a starninum situ describendi, 153.

MOLLIEUX, P., 1914. The composition and food value of fresh soybeans. Ann. Chim. Analyt., 19 (1914), No. **6**: 217–219.

MOOERS, C. A., 1908. Soybeans vs. cowpeas. Tenn. Agric. Exp. Sta., Bull. **82**: 75–104.

MOORE, R. A. and DELWICHE, E. J., 1914. Soybeans—An important Wisconsin crop. Wis. Agric. Exp. Sta., Bull. 236.

1918. Soybeans—A crop worth growing. Wis. Agric. Exp. Sta., Bull. 289.

MORSE, W. J., 1917. Harvesting soybean seed. U. S. Dept. Agric. Farmers Bull. 886.

1918*a*. Soybeans: Culture and uses. U. S. Dept. Agric. Farmers Bull. 973.

1918*b*. The soybean industry in the United States. U. S. Dept. of Agric. Yearbook (**1917**): 101–111. (Separate No. 740), 1918.

MORSE, W. J. and HENDRICK, H. B., 1919. Illustrated lecture on soybeans. U. S. Dept. Agric., Syllabus 35.

MUMFORD, F. B. and WILLSON, C. A., 1911. Pork production with forage crops. Mo. Agric. Exp. Sta., Bull. 95.

MURAI, J., 1897. Analyses of Shoyu. Tokio Eisensiken Iho. **8**: 35.

NEWHALL, C. A., 1920. The direct identification of soybean oil. Jour. Ind. and Engin. Chem. v. 12. No. **12**: 1174–1175.

NEWMAN, C. L., 1901. Oat experiments. Ark. Agric. Exp. Sta., Bull. 66.

NIKITIN, A., 1901. La graine de soja et ses products. Zeit. für Untersuchung der Nahrungs usid. Genussmittel, v. **4**: 39.

NOGAKUSKI, K., 1897. Natto. Bull. of the Coll. of Agric. Tokyo, v. **2**: 68–72.

NOLL, C. F. and LEWIS, R. D., 1921. Culture and uses of soybeans. Pa. Agric. Exp. Sta., Bull. 167.

NOROÑA MACEDA, FELIX, 1919. Selection in soybeans in the Philippines. The Philippine Agriculturist. v. VIII, No. **3**: 92–98. Los Banos, Oct., 1919.

NOZAKUSHI, M., 1897. Tofu. Bull. of the Coll. of Agric. Tokyo, v. **2**: 209-215.

NUTTALL, THOMAS, 1829. Soybean. New England Farmer, v. VIII. No. **14**: 105.

OETTINGER, C. and BUCHTA, F., 1911. Soybean oil. Ztschr. Angew. Chem. 24. No. **18**: 728–829.

Okamoto, H., 1909–10. New species of Phlœothripidæ of Japan. Trans. Sapporo Nat. Hist. Soc. No. **3**: 89–91.

Onodera, N., 1915*a*. On the effects of various substances (electrolytes, nonelectrolytes, alkaloids, etc.) upon the urease of soybeans. Biochem. Jour. No. **32**: 390–392.

1915*b*. On the urease of the soybean and its "coenzym." Biochem. Jour., 9 (1915), No. **4**: 575–590.

Osborn, H., 1912. Enemies-Leafhoppers. U. S. Dept. Agric. Bur. Ent. Bull. 108.

Osborn, H. and Mally, C. W., 1896. Seeds, germination as affected by carbon bisulfide. Iowa Agric. Exp. Sta., Bull. 32.

Osborne, T. B. and Campbell, S. F., 1897. Proteids of the soybean. Conn. Agric. Exp. Sta., Rpt. 21, **1897**: 374–382.

Osborne, T. B. and Mendel, L. B. 1917*a*. The use of the soybean as food. Jour. Biol. Chem., **32**: 369.

1917*b*. The comparative nutritive value of certain proteins in growth and the problem of protein minimum. Jour. Biol. Chem., vol. **20**: 351.

1917*c*. The relative value of certain proteins and protein concentrates as supplements of corn gluten. Jour. Biol. Chem., v. **29**: 69–72.

Oshima, Kintaro, 1905. The soybean and its preparations. U. S. Dept. of Agric. O.E.S., Bull. **159**: 23–33.

Oshima, K. and Ariizumi, M., 1914. On the occurrence of creatinin in leguminous seeds. Jour. Coll. Agr. Tohoku Imp. Univ. 6 (1914), No. **2**: 17–25.

Otis, D. H., 1904. Experiments with dairy cows. Kans. Agric. Exp. Sta. Bull. 125.

Ott de Vries, J. J., 1909. Soybean cake, feeding value. Verslag. Ver. Exploit. Proefzwivel, boerderjii Hoorn: 1439.

Paillieux, A., 1880. Le soya, sa composition chemique, ses varieties, sa culture, et ses usages. Bull. Soc. Acclim. France. ser. 3. annee **7**: 414–471, 538–576.

Pate, W. F., 1918. Soybean harvesters. N. C. Agric. Exp. Sta. Extens., Circ. 80.

Penny, C. L., 1903. Cover crops as green manure. Del. Agric. Exp. Sta., Bull. 60.

Phillips, A. G., Carr, R. H. and Kennard, D. C., 1920. Meat scraps vs. soybean protein as a supplement to corn for growing chickens. Jour. Agric. Res. 18 (1920), No. **7**: 391–398.

Pierre, J. I., 1869. Etudes—de phys. vegetale. v. II. Plantes fourrageres.

Piper, C. V., 1914*a*. A chapter in the botanical history of the soybean. Jour. Amer. Soc. Agron. 6 (1914), No. **2**: 75–84.

1914*b*. Forage plants and their culture, 513–538.

Piper, C. V. and Morse, W. J., 1910. The soybean: history, varieties and field studies. U. S. Dept. Agric. B.P.I., Bull. 197.

1916. The soybean, with special reference to its utilization for oil, cake, and other products. U. S. Dept. Agric. Dept. Bull. 439.

Piper, C. V. and Nielsen, H. T. Soybeans. U. S. Dept. of Agric. Farmers' Bull. 372.

PRAIN, D., 1897. Some additional leguminosæ. Jour. of the Asiatic Society of Bengal. v. 66. pt. 2. No. 2.

PRICE, J. N., 1908. Home-grown rations in economical production of milk and butter. Tenn. Agric. Exp. Sta., Bull. 80.

PRINCE, F. S., 1917. The soybean in New Hampshire. N. H. Agric. Exp. Sta., Bull. 181.

1918. Soybeans for silage. N. H. Agric. Exp. Sta., Press Bull. 96.

PRINSEN, H. C. GEERLIGS, 1896. Einige chinesische Sojabohnenpräparate. Chem. Ztg. v. 20, No. **9**: 67–69.

REGEL, EDWARD AUGUST VON and MAACK, R., 1861. Tentamen floræ usswiensis, 50.

RICHARDS, W. B. and KLEINHEINZ, F., 1904. The value of soybeans as a part of a grain ration for lambs. Wis. Agric. Exp. Rpt. **1903–4**: 51–55.

ROBERT, J. C., 1915. The economic value of the soybean. Miss. Agric. Coll. (Pub.), 1915, July 1.

ROBERTS, G. and KINNEY, E. J., 1912. Soybeans. Ky. Agric. Exp. Sta., Bull. 161.

ROBISON, G. M. and OPPENHEIM, C. J., 1919. Jour. Lab. and Elin. Med. 4, 1919, No. **7**: 448, 449.

ROBISON, W. L., 1920*a*. Soybean oil meal as a feed for swine. Mo. Bull. Ohio Agric. Exp. Sta., 5 (1920), No. **4**: 115–120.

1920*b*. The use of forage crops in the fattening of pigs. Ohio Agric. Exp. Sta., Bull. **343**: 165–222.

ROBISON, W. L., 1921. Supplements to corn for fattening swine. Ohio Agric. Exp. Sta., Bull. 349.

ROSENGREN, L. F., 1910. The influence of soybean cake on the quality of butter. Meddl. Centolanst. Försöksv. Jordbruksomradet., No. 30.

ROUEST, L., 1921. Le Soja et son Lait vegetal.

ROXBURGH, WILLIAM, 1832. Catalogue, **492**: 55.

RUATA, G. and TESTONI, 1907. La Soia nell 'alimentation italiana. Bol. Uffic. Min. Agric. Indust. 3 (Rome). vol. VI: 698–718.

RUMPHIUS, GEORGIUS EVERHARDUS. 1747. Herbarium Amboinense, vol. **5**: 388.

RURÄH, J., 1910. The soybean as an article of diet for infants. Jour. Amer. Med. Assoc., v. **54**: 1665–1665.

1911. Soybean Cookery. Med. Rec. (N. Y.), v. **80**: 526–627.

1915. The soybean and condensed milk in infant feeding. Amer. Jour. Med. Sci., 150 (1915), No. **4**: 502–512.

SAHR., C. A., 1912. Soybean. Hawaii Agric. Exp. Sta., Rpt. **1913**: 46.

SAVI, GEATONA. 1824. Osservazioni sopra i generi Phaseolus et Dolichos. Memoria 1–3, 1822–5, in Nuovo Giornale de Letterati Pisa **8**: 113.

SAWER, E. R., 1910. The soya bean. Studies in agriculture. Division of Agriculture and Forestry. Natal.

1911*a*. Experiments with soya beans in 1910–1911. Agric. Jour., union of South Africa, v. **2**: 161–175.

1911*b*. Soya beans. Cedara Memoirs in South African agriculture. Pietermaritzburg Govt., v. **2**: 183–218.

SCHMITZ, N., 1917. Soybeans. Md. Agric. Exp. Sta., Bull. 201.

SCHMITZ, N. and MACDONALD, PEARL. 1917. Soybeans. The soybean as human food. Pa. Agric. Exp. Sta. Ext., Circ. 59.

SCHULZE, E., 1899. Sur les constituents azotes des graines de soja. Zeit. für physiol. chem., XII: 465.

SCHULZE, E. and FRANKFURT, S., 1894. Ueber die Verbreitung des Rohrzuckers in der Pflanzensamen. Ber. Deut. Chem. Gesell., No. **27**: 62.

SETTINJ, L., 1912. Soybean oil. Ann. Lab. Gabelle **6**: 461.

SHECUT, J. L. E. W., 1806. Soybean Flora Caroliniensis, v. **1**: 514.

SHEDD, O. M., 1914. The relation of sulphur to soil fertility. Ky. Agric. Exp. Sta., Bull. 188.

SHEET, E. W. and LUCKWILLER, R. H., 1920. Effect of winter rations on pasture gains of yearling steers. U. S. Dept. Agric. ,Bull. 870.

SHERMAN, F., 1920. The green clover worm (Plathypena scabra Fahr.). Jour. Econ. Ent. 13 (1920), No. **3**: 295–303.

SHERMAN, F. and LEIBY, R. W., 1920. Green clover worm as a pest of soybeans. N. C. Agric. Exp. Sta. Extens., Circ. 105.

SHIVE, J. W., 1916. The influence of various salts on the growth of soybeans. Soil Sci., v. 1. No. **2**: 163–170.

SHUNK, I. V. and WOLF, F. A., 1921. Further studies on the bacterial blight of soybeans. Phytopath., **11**: 18–24.

SHUSTER, G. L., 1922. Influence of fertilizers on yield and maturity of soybeans. Jour. Amer. Soc. Agron., v. 14. No. **5**: 193.

SIEBOLD, PHILLIP FRANZ VON, and ZUCCARINI, J. G., 1845. Floræ Japoniæ familiæ naturales, adjectis generum et specierum exemplis selectis. Abh. Akad. Muenchen, v. 2. pt. **2**: 119.

SINCLAIR, J. F., 1916. Recent observations in the use of soybeans in infant feeding. N. Y. State Jour. Med., 16 (1916) No. **2**: 83–88.

SKINNER, J. H., 1905. Soybeans, middlings, and tankage as supplemental feeds in pork production. Ind. Agric. Exp. Sta., Bull. 108.

SKINNER, J. H. and COCHEL, W. A., 1908. Supplements to corn for fattening. Ind. Agric. Exp. Sta., Bull. 126.

SKINNER, J. H. and KING, F. G., 1913. Steer feeding, pt. IV. Soybean meal vs. cottonseed meal in rations for fattening steers. Ind. Agric. Exp. Sta., Bull. 167.

1914. Cattle feeding. pt. IV. Ground soybeans vs. cottonseed meal as supplement to rations for fattening steers. Ind. Agric. Exp. Sta., Bull. 178.

SKINNER, J. H. and KING, F. G., 1915. Cattle feeding. pt. II. Ground soybeans vs. cottonseed meal as supplement to rations for fattening steers. Ind. Agric. Exp. Sta., Bull. 183.

1917. Feed for lambs. Fattening Western lambs. Ind. Agric. Exp. Sta., Bull. 202.

SKINNER, J. H. and STARR, C. G., 1918. Sheep feeding. Fattening western lambs. Ind. Agric. Exp. Sta., Bull. 221.

SKINNER, J. H. and VESTAL, C. M., 1919. Winter steer feeding (soybean silage). Ind. Agric. Exp. Sta., Bull. 240.

SMETHAN, A., 1909. Some new feeding stuffs and their relative values as cattle foods. Roy. Lancashire Agr. Soc. Jour.: 28–45.

SMITH, A. G. and HOPE, C. E., 1920. Farm practices with soybeans. N. C. Dept. of Agric. v. 41, No. 45, whole No. 267.

SMITH, C. D., 1905. Legumes other than alfalfa. Mich. Agric. Exp. Sta., Bull. 227: 167–184.

SMITH, C. D. and ROBINSON, F. W., 1905. Observations on the influence of nodules on the roots upon the composition of soybeans and cowpeas. Mich. Agric. Exp. Sta., Bull. **224**: 127–132.

SMITH, L. B., 1919. The green clover worm a pest of soybeans (Plathypena scabra). Quart. Bull. Va. State Crop Pest Comm., 1 (1919), No. 3.

SMITH, W. C., 1915. Chinch bugs. Country Gentleman, April 10, **1915**: 686.

SOULE, A. M. and FAIN, J. R., 1904. Silage crops. Tenn. Agric. Exp. Sta., Bull. v. XVII, No. 1.

SOULE, A. M. and VANATTER, P. O., 1907. Feeding value. Va. Agric. Exp. Sta., Bull. **168**: 277–282; 288–290.

SOULE, A. M., VANATTER, P. O. and FAIN, J. R., 1901*a*. Fertilizing constituents. Tenn. Agric. Exp. Sta., Bull. 14. No. **1**: 22–24.
1901*b*. Variety test. Tenn. Agric. Exp. Sta., Bull. 104. No. **1**: 9–19.

STOCKMAN, S., 1916. Poisoning from feeding soybean meal. Jour. Comparative Pathology and Therapeutics. 95.

STIF, A., 1889. Sur la composition de la sauce. Jahresberichte uber der Fortschritte der Pharmakognosie. Pharmacie und Toxicologie.

STINGL, J. and MORAWSKI, TH., 1886. Zur Kenntniss der Sojabohne. Chem. Zt. Reptor. **10**: 140, Monatsh. Chem. **7**: 176–190.

STREET, J. P., 1906. Analyses. N. J. Agric. Exp. Sta., Rpt. **1906**: 37.
1912. Analyses. Soybean gruel flour. Conn. Agric. Exp. Sta., Rpt. **1912**: 109.
1914. Analyses. Soybeans and soybean fodder. Conn. Agric. Exp. Sta., Rpt. **1913**: 225.
1915. Soybean analyses. Conn. Agric. Exp. Sta., Rpt. 1914. pt. **4**: 199–220.

STREET, J. P. and BAILEY, E. M., 1915. Carbohydrates and the enzymes of the soybean. Jour. Indus. and Engin. Chem. 7 (1915), No. **10**: 853–858.

STROUD, W. H., 1921. The forms of nitrogen in soybean nodules. Soil Sci., **11**: 123–130.

STUTZER, A., 1907. Investigations on the effect of nitrite and inoculating soil on soybeans. Jour. Landw. 55 (1907). No. **1–2**: 78–80.

SUZUKI, U., ASO, K. and MATARAI, H., 1907. Chemical composition of soy sauce or shoyu. Bull. Coll. Agr. Tokyo Imp. Univ. **7**: 477–494.

TAKEUCHI, T., 1909. The occurrence of urease in higher plants. Jour. Coll. Agric. Imp. Univ. Tokyo 1. No. **1**: 1–14.

TAKIMOTO, SEITO, 1921. Bacterial spotting disease of soybean. Jour. Plant Prot. **8**: 237–241.

TAVERNE, N. J. A., 1913. De oxydatie en de polymerisatic van sojaolie. Seiden, E. Jjdo (Proefschrift-Delft), Literatur overseiht: 3–17.

TEN EYCK, A. M. and CALL, L. E., 1909. Cowpeas. Kans. Agric. Exp. Sta., Bull. 160.

TERAO, H., 1918 Maternal inheritance in the soybean. Amer. Nat. **52**: 51–56.

THOMPSON, ALICE R., 1917. Chemical studies of the efficiency of legumes as green manures in Hawaii. Hawaii Agric. Exp. Sta., Bull. 43.

Thompson, F. and Morgan, H. H., 1912. Soybean oil. Del. Agric. Exp. Sta., Bull. 99.

Thompstone, E. and Sawyer, A. M., 1914. The peas and beans of Burma. Dept. Agric. Burma., Bull. 12.

Thunberg, C. P., 1784. Flora Japonica: 282.

Tisdale, W. H., 1918. Bacterial blight of soybean. N. C. Agric. Exp. Sta., Rpt. **1918**: 59.

Toch, M., 1912. Soya bean oil for paint purposes. Jour. Chem. Indus. v. **31**: 572–574.

Tollens, G. B., 1888. Handbuch der Kohlenhydraten. v. **1**: 208.

Tonnelier, A. C., 1912. La Soja Hispida y sus Aplicaciones. Buenos Aires, 1912.

Tournefort, J. P., 1730. The Compleat Herbal or the Botanical Institutions of J. P. Tournefort, v. 2. 481.

Trimen, H., 1894. Handbook of the Flora of Ceylon, pt. **2**: 72.

Tsuda, S., 1909. On the different forms of phosphoric acid in organic manures. Jour. Coll. Agric. Imp. Univ. Tokyo 1 (1909). No. **2**: 160–170.

Vestal, C. M., 1922. Soybean and mineral supplements for fattening hogs. Ind. Agr. Exp. Sta. Report of Progress, Summary H.–6.

Vilmorin-Andrieux, 1891. Le plantes potageres. Paris.

Voigt, J. O., 1845. Hortus Suburbanus Calcuttensis: 231.

Voorhees, E. B. and Lane, C. B., 1898. Soiling crops of milch cows. N. J. Agric. Exp. Sta., Bull. 130.

Voorhees, J. H., 1913. The soybean in New Jersey. N. J. Agric. Exp. Sta., Circ. 21.

1915. Variations in soybean inoculation. Jour. Amer. Soc. Agron. 7 (1915). No. 3. 139–140.

Wakerly, F., 1909–10. Soya-cake vs. linseed-cake for feeding dairy cows. Midland Agric. and Dairy College. Bull. 9.

Wallis, T. E., 1913. The structure of the soybean. Pharm. Jour. (London). 4 ser. 37 (1913), No. **2597**: 120–123.

Washburn, W. F., 1916. Soybean oil. N. D. Agric. Exp. Sta., Bull. 118. pt. 1.

Watson, G. C. and Mairs, T. I., 1903. Forage plants for soiling, culture. Pa. Agric. Exp. Sta., Bull. 65.

1904. Feeding experiments with milch cows. Pa. Agric. Exp. Sta., Rpt. 1904, pt. **2**: 174–182.

1905. Forage plants for milch cows. Pa. Agric. Exp. Sta., Bull. 75.

Weaver, L. A., 1921. Hogging down corn and soybeans. Mo. Agric. Exp. Sta., Bull. 179.

Wein, E., 1878. Ernteresultate der auf der Versuchstation Angestellten culturversuche. Zeits. des Land. in Bayern. 469.

1879. Ueber der anbau der rauhhaarigen Sojabohne in Bayern. Zeits. des. Land. Ver. in Bayern. 64–68, 98–113.

1881. Die Sojabohne als Feldsfrucht. Journ. für Land. XXIV. Jahrg. Supplementheft.

Weiske, H., 1879. Futteransnutzung-versuche mit sojabohnen-stroh und shalen, ausgefuhrt auf der Versuchs-station Proskan. Jour. Landw. Jahrg. **27**: 511–520.

Wester, D. H., 1916. The cause of the ureolytic action of soybeans. Chem. Weekbl., 13 (1916). No. **24**: 663–677.
1919. The urease content of seeds. Chem. Weekbl., 16 (1919), No **51**: 1548–1556.
1919. The urease content of different varieties of soybeans. Chem. Weekbl. 16 (1919). No **51**: 1552–1556.
1920. Ueber den merkurdigen Verlaub der urease wirkung eines Sojabohnenextraktes beim erwarmen auf 37. Pharm. Zentralhalle **61**: 293–295.

Wheeler, G. C. and Wright, T. R. H., 1913. A comparison of tankage and soybean meal as a supplement to corn for fattening hogs. Kans. Agric. Exp. Sta., Bull. **192**: 364.

White, B., 1916. The soybean industry of eastern North Carolina. N. C. Agric. Exp. Sta., Extens. Circ. 9.

White, H. L., 1919. The modification of the composition of vegetable oils, with special reference to increasing unsaturation. Jour. Indust. and Engin. Chem. 11 (1919). No **7**: 648–651.

Whitson, A. R., 1902. Soybeans, water requirement. Wisc. Agric. Exp. Sta., Rpt. **1902**: 190–191.

Whittier, A. C., 1916. A study of soybean hay. Del. Agric. Exp. Sta., Bull. 112.

Wiancko, A. T. and Cromer, C. O., 1920. Soybeans in Indiana. Ind. Agric. Exp. Sta., Bull. 238.

Wiancko, A. T., Fisher, M. L. and Cromer, C. O., 1914. Soybeans and Cowpeas. Ind. Agric. Exp. Sta., Bull. 172.

Williams, C. B., 1915. Soybean growing in North Carolina. N. C. Agric. Exp. Sta., Circ. 31.
1916*a*. The commercial use of the soybean. N. C. Agric. Exp. Sta., Extens. Circ. 29.
1916*b*. Soybean products and their uses. N. C. Agric. Exp. Sta., Extens. Circ. 34.
1917. Soybeans—A future economic factor in North Carolina. N. C. Agric. Exp. Sta., Extens. Circ. 57.

Williams, C. G., 1908. The soybean. Ohio Agric. Exp. Sta., Circ. 78.
1918. Livestock vs. grain farming. Ohio Agric. Exp. Sta., Bull. 328.

Williams, C. G. and Park, J. B., 1917. Soybeans: Their culture and uses. Ohio Agric. Exp. Sta., Bull. 312.

Williams, C. G. and Welton, F. A., 1913. Cooperative test with soybeans in 1912. Ohio Agric. Exp. Sta., Circ. 132.
1912. The soybean and cowpea. Ohio Agric. Exp. Sta., Bull. 237.

Williams, T. A., 1899. The soybean as a forage plant. U. S. Dept. Agric. Farmers' Bull. 58

Willson, C. A., 1912. Feeding experiments with steers. Tenn. Agric. Exp. Sta., Rpt. **1912**: 57–58.
1915. Relation of steer feeding to farm returns. Tenn. Agric. Exp. Sta., Bull. 114.

Wilson, J., 1894. Soiling milch cows. Iowa Agric. Exp. Sta., Bull. **27**: 85–124.

Wilson, J. K., 1915. Physiological studies of Bacillus radicicola of the soybean. Abs. in Science. n. ser., 41 (1915). No. **1048**: 180.

1917. Physiological studies of Bacillus radicicola of soybean (Soja max Piper) and factors influencing nodule production. N. Y. (Cornell) Agric. Exp. Sta., Bull. 386.

Windsor, Wenona, 1918. How to cook soybeans and cowpeas. Mo. Agric. Exp. Sta., Extens. Circ. 45.

Winters, R. Y. and Herman, V. R., 1921. Soybeans for the Piedmont and mountain sections of North Carolina. N. C. Agric. Exp. Sta., Extens. Circ. 111.

Winton, A. L., 1906. Diabetic foods. Conn. Agric. Exp. Sta., Rpt. 30, **1906**: 153–165.

Wisconsin Agric. Exp. Sta., Bull. 323 (1920). Report of field crops work in Wisconsin, 1919–20.

Wisconsin Agric. Exp. Sta., Bull. 302 (1919). p. 35. Report of field crops work in Wisconsin, 1917–18.

Van der Wolk, P. C., 1916. Study of a bacterial disease of soybean and the nature of the root nodules of Glycine soja and Arachis hypogaea. Cultura, 28 (1916) Nos. **336**: 268–285; **377**: 300–319.

Wolf, F. A., 1920. Bacterial blight of soybean. Phytopath. 10 (1920). No. **3**: 119–132.

Wolf, F. A. and Lehman, S. G., 1920. Bacterial blight. N. C. Agric. Exp. Rpt. **1920**: 57.

Wolkoff, M. I., 1918. Effect of ammonium sulfate in nutrient solution on the growth of soybeans in sand cultures. N. J. Agric. Exp. Sta., Sta., 43rd Ann. Rpt. **1917**: 416–419.

Woll, F. W. and Humphrey, G. C., 1904. Soybean silage as a food for dairy cows. Wis. Agric. Exp. Sta., Rpt. **1903–4**: 67–74.

Woll, F. W. and Olson, G. A., 1907. The effect of soil inoculation on the distribution of the fertilizer ingredients in soybeans. Wis. Agric. Exp. Sta. 24th Ann. Rpt. **1906–07**: 164–166.

Woodhouse, E. J. and Taylor, C. S., 1913. Varieties of soybeans in Bengal. Mem. Dept. Agric. India, Bot. ser. 5, **31**: 105–175.

Woods, C. D., 1890. Fertilizing ingredients in crop and roots of legumes. Conn. Agric. Exp. Sta. (Storrs), Bull. 6 pp. 29–36.

1914. Culture of soybeans in Maine. Maine Agric. Exp. Sta., Bull. 224.

Woods, C. D. and Bartlett, J. M., 1904. Soybeans in Maine. Maine Agric. Exp. Sta., Bull. **106**: 113–121.

Woodworth, C. M. and Brown, F. C., 1920. Studies on varietal resistance and susceptibility to bacterial blight of the soybean. Abs. in Phytopath. 10(1920). No. **1**: 68.

Yabe, K., 1895. Uber einen vegetabilischen kase aus sojabohnen. Landw. Vers. Stat., Bd. **45**: 438–439.

Zavitz, C. A., 1916. Results of cooperative experiments in agriculture. Ann. Rpt. Ontario Agric. and Expt. Union. 38 (**1916**): 9–33.

1919. Variety test of soybeans. Ontario Agric. Exp. Sta., Bull. 268.

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